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A MANAGEMENT INFORMATION SYSTEM FOR CONSTRUCTION MANAGEMENT LESSONS-LEARNED

THESIS

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AFIT/GEM/LSM/89S-17

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THESIS

Presented to the Faculty of the School of Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
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Abstract

This thesis was based on the hypothesis that Air Force Civil Engineering construction managers could lessen the impact of inexperience through the use of lessons-learned. The thesis examined the potential for developing an on-line management information system (MIS) to provide better storage and retrieval of lessons-learned. Emphasis was placed on developing a WANG-based system that would be accessible at all levels of Civil Engineering construction.

Research consisted of reviewing MIS development methodologies, investigating several existing information systems - both general and lessons-learned oriented - and determining the users' requirements for the proposed MIS.

The objective of this research was to identify factors and procedures that should be considered when developing a construction management oriented, lessons-learned management information system for the Civil Engineering WANG computer. The process involved reviewing pertinent literature, logging onto and using existing on-line information systems and interviewing construction managers at the MAJCOM and AFRCEs.

Conclusions from this research indicated on-line information systems are well suited to lessons learned. All of the AFRCE construction managers interviewed stressed additional use of lessons-learned is necessary. Further,

construction managers stated the proposed system should be WANG-based, menu-driven, user-friendly and easily adaptable to the changing needs of the user. Menus and system characteristics for a prototype lessons-learned MIS are outlined in the research. The author recommended a WANG-based lessons-learned MIS prototype be developed, using the research findings as a starting point, with further refinement through a more broad-based, user involvement.

A MANAGEMENT INFORMATION SYSTEM FOR CONSTRUCTION MANAGEMENT LESSONS-LEARNED

I. Introduction

General Issue

The primary mission of United States Air Force (USAF) Civil Engineering (CE), as outlined in Air Force Regulation 85-10, Operations and Maintenance of Real Property, includes the acquisition, construction, maintenance and operation of real property facilities (AFR 85-10: 2). With an annual construction budget approaching a billion dollars, the construction portion of this mission is significant (Majdanik, 1989).

To meet mission requirements, Civil Engineering uses a combination of in-house and contract work forces (AFR 85-1: 88). As reductions in manpower shrink the size of in-house work forces, Civil Engineering must increasingly rely on construction contracts to accomplish real property maintenance, repair and modification. Unfortunately, frequently the military personnel who manage construction are young and do not have the requisite experience.

A national field survey of all principle parties in construction contracts (owners, contractors, construction managers, clients, etc.), including the U.S. Army Corps of

Engineers, the Naval Facilities Engineering Command and the Air Force, found that up to 76 percent of the owners and contractors felt that inspectors did not have the necessary experience to inspect construction work (Task Committee on Inspection, 1972: 219-234).

Within Air Force Civil Engineering, the problem of inexperienced inspectors is even more pervasive. Williams surveyed design engineers, contract administrators, contract management chiefs and inspectors to evaluate their perceptions of Air Force inspectors' job performance. The research found "significant reservations" about the capabilities and experience of inspectors across almost all respondents. Williams verified that within Civil Engineering, a "lack of inspector experience and training continually surfaced as a problem" (Williams, 1986: 1-5, 72).

USAF construction managers at all levels -- base, major command (MAJCOM), Air Force Regional Civil Engineer (AFRCE), and Air Staff -- document negative lessons-learned, or common pitfalls, in construction management and ways to avoid them (Bradshaw, 1988). Similarly, throughout the Air Force, individual bases and personnel have found positive lessons-learned, i.e. construction methods, materials and techniques, that work extremely well. Without a clear method of consolidation and dissemination of this critical information, however, construction managers frequently repeat the same errors instead of learning from past

mistakes of others. Likewise, when a particularly successful method or material is found, the benefit of that discovery is not shared with other inspectors in the Air Force. Experience, or the ability to recall and use past lessons-learned, greatly reduces the recurrence of common mistakes and increases the use of successful techniques.

Specific Problem

Air Force Civil Engineering construction contract inspectors are inexperienced and frequently fail to benefit from the experiences of others. A methodology is needed to develop an on-line computer-based management information system containing construction management lessons-learned to improve information crossfeed.

Scope and Limitations

The research scope was limited to determining the requirements necessary to develop a WANG based lessons-learned MIS from an end-user's perspective. A WANG based system was selected as the WANG computer is common to virtually all CE organizations. The specific area of research focused on construction managers of large construction projects managed by the AFRCEs, either independently or with the assistance of the Army Corps of Engineers or the Naval Facilities Command. Construction managers of large scale projects were selected as the "end-users" because they typically have the most experience of all CE construction managers.

Objective

The research objective was to identify factors and procedures that should be considered when developing a construction management oriented "lessons-learned" management information system for the Civil Engineering WANG computer.

Research Questions

The following research questions were used to reach the objective stated above:

1. How are generic management information systems developed?
2. Are there on-line "lessons-learned" management information systems in use? If so, how have these systems been developed?
3. What common factors made the existing systems successful or less than successful?
4. How should a WANG-based lessons-learned system be developed to meet the needs of AF construction managers?
5. From the user's perspective, how should the WANG lessons-learned MIS be structured?

Justification

Civil Engineering managers from Air Staff to base level recognize lessons-learned feedback and crossfeed can yield substantial benefits and, to a great extent, buffer the impact of inexperience. HQ USAF Engineering and Services Installation Development Division (HQ USAF/LEEDP) initiated an investigational engineering program project specifically for the development of computer software for facility

acquisition lessons-learned (Schmidt, 1989). Proponents of this project are convinced,

> Lessons-learned in Air Force construction are not effectively utilized. The lack of a central databank of information on facilities acquisitions lessons-learned allows our component activities to repeat mistakes instead of learning from others. (Bradshaw, 1988)

The Air Force Engineering and Services Center (AFESC) at Tyndall AFB has initiated a "Reliability and Maintainability Lessons-learned Program to enhance the quality and performance of facilities and supporting systems" designed, built and maintained within the Air Force by Civil Engineering (Wentland, 1989). To support the Reliability and Maintainability Lessons-learned Program, AFESC is currently working to ease and improve the flow of information among CE units throughout the Air Force by upgrading the telecommunication capabilities of the Work Information Management System (WIMS) installed at 119 CE locations world-wide (Wentland, 1989).

All of the Air Force Regional Civil Engineers (AFRCEs), contacted in the U.S. expressed concerns about the need to make better use of lessons-learned. Colonel Ralph Hodge, at the Western Division AFRCE, said

> Using past experiences to improve future performance is crucial if we want to stay in the construction business. A prototype hospital project recently completed here had hundreds of good, solid lessons on how to build a hospital. All we lack is a way to collect and share those lessons. (Hodge, 1989)

Gary Lynne, at the Central Division AFRCE in Dallas, related how the Central Division AFRCE continually strives to learn from past experiences, including the recent gathering of nine architectural firms who have worked with AFRCE Central together to

> ...talk about all the things we have done right, and all the things we are doing wrong. If we don't take the time to learn from previous lessons we'll repeat our failures and miss out on a lot of potential successes. (Lynne, 1989)

Lynne acknowledged this as only one approach to learning from past experiences and stressed much more can and should be done in the area of lessons-learned. According to Lynne,

> Quite frankly, we aren't making as much use from our past experiences as we should. There is unfortunately no real, formal feedback system available... but one is definitely needed. A computerized system on the WANG is an option that should be explored. (Lynne, 1989)

Charles Smith, at the Eastern Division AFRCE in Atlanta, echoed the sentiments of his counterparts as he explained,

> Internal to each AFRCE, the Branch Chiefs and Project Managers are responsible for crossfeeding lessons-learned. In-house this is done fairly well, but it's still less than perfect. We try to make maximum use of crossfeed. Externally, crossfeed between the various AFRCEs is even less efficient. Right now there is no official feedback system...there should be, but there isn't. (Smith, 1989)

Gary Erickson, at the Strategic Air Command AFRCE at Offutt AFB, has made tremendous use of lessons-learned to improve SAC's facility acquisition program. AFRCE SAC employs both an automated and manual approach to lessons-learned.

AFRCE SAC developed a WANG-based lessons-learned program "to combine the lessons-learned from over 25 SAC bases and get a look at what's going on across the command" (Erickson, 1989). A hard copy booklet of lessons-learned has also been written regarding the B-1B program recently completed by AFRCE SAC. This booklet is for the bases' and Army Corps of Engineers (COE) district engineers' use (Erickson, 1989). The AFRCE SAC lessons-learned WANG program is still in the development stages.

Although monetary savings yielded through the use of lessons-learned are at best only an estimation, an analysis based purely on historical data provides at least a reasonable assessment of the rough order of magnitude of potential savings. For example, it is an accepted reality that virtually all facility construction contracts are modified or changed during the construction process. In fact, for planning purposes, the cost of most government construction projects can be expected to increase "25 to 30 percent over the life of the project, from inception to completion" (Majdanik, 1989). Using these percentages, over $200 million of the Air Force $868 million FY90 Military Construction Program (MCP) budget may be due to project changes. If only a small percentage of those project changes costs could be avoided by the application of lessons-learned, monetary savings would be substantial. Tucker concurs with this assessment and notes that due to widely varying facility construction costs, scope and

complexity, "Lessons-learned... cannot be quantified into savings of time and money. Yet large savings of time and money are possible." (Tucker, 1984: 1).

Nonmonetary costs of not using lessons-learned are equally difficult to quantify. However, the results of failing to benefit from past experiences are apparent in many areas. For example, Keller researched the causes of functional deficiencies in tactical aircraft maintenance facilities and discovered that a primary cause of the functional deficiencies was "most maintenance facilities are designed as one-of-a-kind without the benefit of lessons-learned from construction of similar type facilities" (Keller, 1987: 59). The research concluded failure to benefit from lessons-learned created a "negative impact on the efficiency of maintenance operations and the number of man-hours normally required to perform various tasks" (Keller, 1987: 59).

While Keller considered only tactical aircraft maintenance facilities, the USAF builds several other standard facilities such as housing, administrative, child care, dormitories, gymnasiums, etc. every year. Each of these facilities is built with the same methodology as the maintenance facilities addressed by Keller, without the benefits of lessons-learned. When the "negative impact on the efficiency" of operations noted by Keller in maintenance facilities is multiplied across all facilities, the

nonmonetary impact of failing to use lessons-learned in facility acquisition also becomes substantial.

Background

Knowledge of two distinctly different subjects is needed to understand the research problem. The subject areas in question are Air Force construction contracting and management information systems. This section provides knowledge necessary to understand why experience is crucial to construction management. Further, this section explores how an MIS can provide "experience" to the unexperienced.

First, this section provides a brief overview of the Air Force construction contract process, leading to an in-depth look at the sub-area of construction management. The construction management sub-area details the primary responsibilities and necessary qualifications of construction managers or inspectors. A principle qualification of construction managers is experience.

Second, this section provides an overview of 1) what a management information system (MIS) is and, 2) how an MIS may be used to collate, organize, store and retrieve the collective experiences or "lessons-learned" of Air Force construction managers.

Air Force Construction Contract Process. Merrill and Torchia provide an excellent overview of the Air Force construction contract process, sufficiently simplified for this research, yet still accurate. A construction contract

is a legal agreement between two parties, the owner and the contractor. The contractor is hired to perform construction for the owner. A construction contract is generally used when a valid work request exceeds the capabilities of USAF Civil Engineering. The principle parties in the construction contract process are the user (originator of the work requirement), the contracting officer, the designer, the construction manager (on relatively small jobs this is also the inspector), and the contractor. For purposes of control, authority to direct the contractor is limited to the contracting officer. However, within the scope of the contract, the construction manager has indirect control over the contractor. The user and designer are involved in the contractual process in a third party role, with their interests being brought to the contractor by the construction manager (Merrill and Torchia, 1982: 5-8). These relationships are shown in Figure 1.

Typically, the construction manager for small maintenance and repair construction efforts falls into one of three groups - a) lieutenant or young captain, b) mid to low-range noncommissioned officer in the E-4 to E-6 grade levels, or c) civilian in the GS-7 to GS-10 grade levels. Of these groups, the military construction managers tend to be the least experienced, primarily due to frequent rotation among jobs and bases (Meister, 1989).

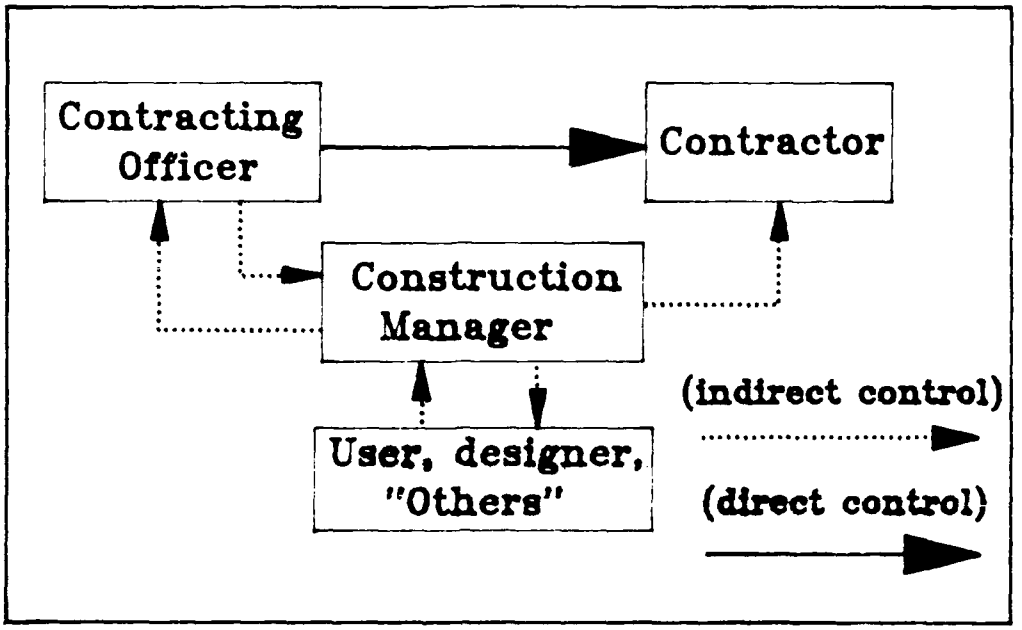


Figure 1. Contract Relationships
(Merrill and Torchia, 1982: 5-8)

MCP Projects. One variation on the description of the Air Force construction process provided by Merrill and Torchia concerns large scale construction projects funded and built under the Military Construction Program (MCP). The design and construction management of large scale MCP projects are accomplished for the Air Force by either the Army Corps of Engineers (COE) or Naval Facilities Engineering Command (NAVFAC). Although the COE and/or NAVFAC perform as the design and construction agent for the Air Force, the Air Force provides a project manager for each MCP project interface between the Air Force and the COE or NAVFAC (AFR 86-1, 1984: 1-20). The relationships of the key players in the MCP contractual process are shown in Figure 2 on the following page.

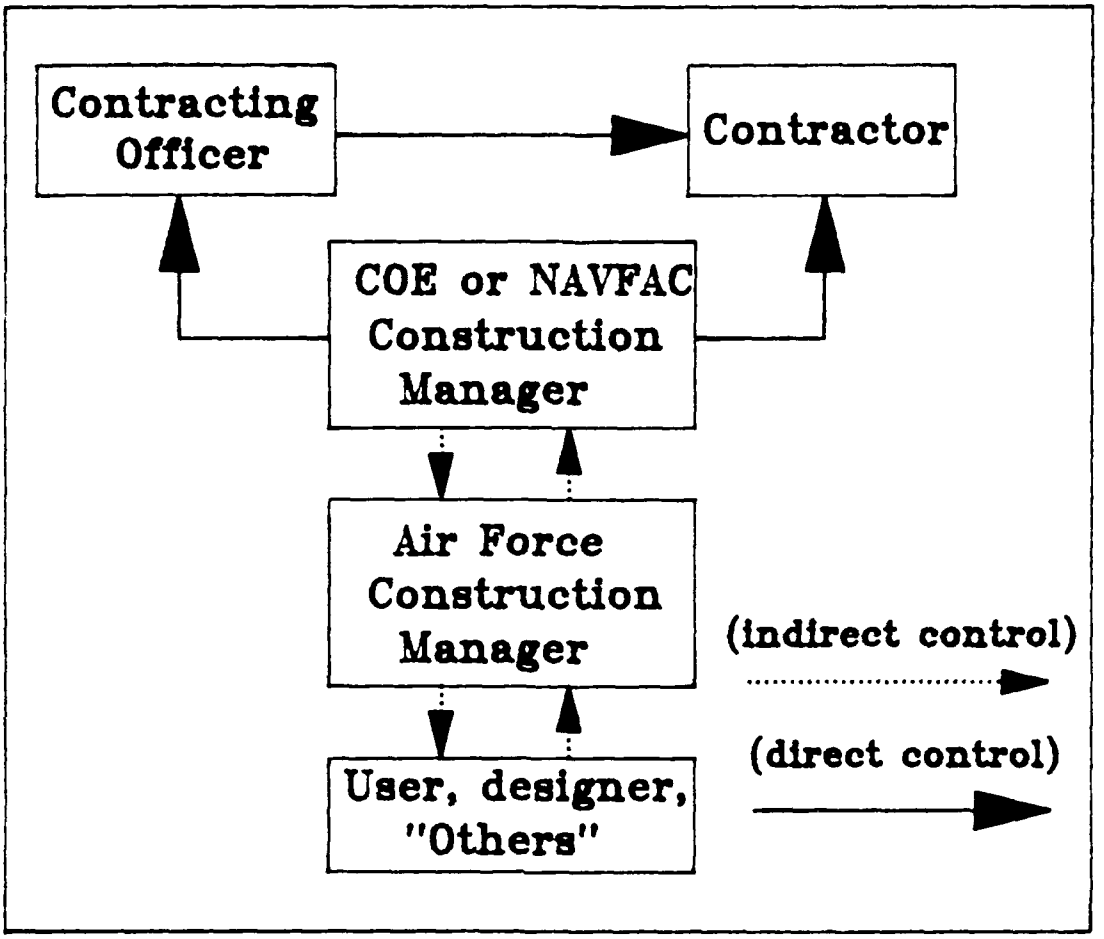


Figure 2. MCP Contractual Relationships (Beally, 1989)

Within the MCP arena, the AF project manager is in a unique position. Charged with the responsibility for ensuring the COE/NAVFAC provide the facility being paid for by the Air Force, the AF project manager often feels frustrated by his lack of control. Examples of difficulties experienced by Air Force project managers on MCP projects are plentiful. AF project managers on MCP projects are not allowed to participate in contract negotiations. Frequently results of negotiations are not provided in a timely manner

to the USAF. Secrecy on the part of the COE often adds to the AF project manager's suspicions that the COE finds it easier to request more money from the Air Force than to oppose a contractor's claims. The relationships between the AF project manager and the COE/NAVFAC construction management staff are often strained by the bureaucracy of the two separate services (Tucker, 1984: 47-50).

The information above is provided not as an indictment of COE or NAVFAC; on the whole, they can and do provide an outstanding service to the Air Force in construction management. This information is offered instead to demonstrate that under the MCP process, AF construction managers must rely even more heavily on experience than their non-MCP counterparts. Keller noted that the COE does "not use a lessons-learned system to improve the designs of like facilities" (Keller, 1987: 56). Equally disturbing, Tucker stressed that although the experience should match the job, frequently,

> This isn't easy to accomplish because the people with needed expertise have good permanent jobs and they are not anxious to leave them for a two or three year construction project. ... The COE has a problem with lower grades in its field offices. Traditionally, Corps of Engineers district staffs hold higher government service grades than its field staffs. Thus, the expertise gravitates to the stable district staff while field offices generally are undergraded and understaffed. (Tucker, 1984: 50)

Construction Management. Construction management consists of controlling administrative, legal, financial and behavioral elements of the construction process (Levitt,

1987: 86). Within the Air Force, construction is governed by Air Force Regulation 89-1 (AFR 89-1), Design and Construction Management. AFR 89-1 outlines the responsibilities, policies and procedures necessary for the construction of Air Force facilities (AFR 89-1:1-1). According to AFR 89-1, the main purpose of construction management/inspection is to ensure the contractor adheres to the approved drawings and specifications (AFR 89-1: 13-1). The key responsibilities of the construction manager as outlined in AFR 89-1 follow.

The inspector must have an understanding of construction practices that will allow recognition of improper construction. The inspector must possess a thorough knowledge of pertinent contracting regulations to evaluate whether or not the contractor is in compliance with the specifications. Although the inspector does not have contractual authority to direct the contractor, the inspector is the technical representative of the contracting officer. In this capacity, it is the construction manager who must recognize a problem exists, initiate a conference between the contracting officer, the construction manager and the contractor and "assist in the interpretation of the technical provisions and contractual documents" to resolve the problem (AFR 89-1: 13-1 to 13-4).

The recurrent theme in these AF construction manager responsibilities is knowledge. As a profession, construction management relies on knowledge based on

experience, rather than knowledge based on education (Levitt, 1987: 88). Many projects have proven the availability of experience is directly related to construction project success (Ashley, 1987: 74). Unfortunately, as stated earlier, CE inspectors lack a significant amount of experience in construction management.

A structured approach is needed to capture the limited individual experiences of the many construction managers in the Air Force. Once captured and organized this pool of experience in the form of lessons-learned can then be made available to all CE construction managers. There are various methods or approaches suitable to solving this problem, which when reduced to its most basic level, is simply one of information sharing. Management information systems are well suited to the task of information sharing, and were therefore explored.

Management Information Systems. "Management information system" is a common term that has been applied to a variety of computers, software programs and other assorted information tools used by today's managers. Lucas defines an information system as "a set of organized procedures that, when executed, provides information to support decision making and control of the organization" (Lucas, 1986: 10). Sprague noted that management information systems were the first attempts of information systems professionals to provide managers with the

information that is critical to effective and efficient job performance (Sprague, 1980: 10-26).

Management information systems can be either manual or computer based. According to Lucas, management information systems have been around much longer than the term MIS, coined in the late 1960s.

> Since people first inhabited the earth, there have been information systems. Individuals, organizations, and nations have always collected and processed "intelligence". Early information systems were highly informal and involved the exchange of news, stories, and anecdotes with neighbors. (Lucas, 1986:11)

As noted by Sprague, management information systems increase both the effectiveness and efficiency of managers by providing information. Viewed from a slightly different perspective, management information systems are essentially a vehicle for information sharing. In the case of Air Force construction managers trying to overcome limited experience, the information needed to be shared consists of the positive and negative lessons-learned by their predecessors and counterparts.

Information sharing has made tremendous gains with the widespread use of computers. Senn notes,

> Computer based information systems make possible the smooth and efficient operations of airline reservations offices, hospital records departments, accounting and payroll functions, electronic banking, telephone switching systems and countless other applications, both large and small. (Senn, 1984:4)

There are a plethora of computer based information sharing systems on-line and available for use by the public

and commercial sectors. The diversity of the information available can be seen in the following few examples: Defense Technical Information Center (DTIC), NOAA National Meteorological Database, Biology Network, Lunar and Planetary Institute Library Information Center, Automated Case Information Management System, Antitrust Management Information System (Zarozny, 1987). Other on-line systems such as COMPUSERVE offer a single point source of information on various subjects from the stock market and real estate investments to electronic travel services and shopping via computer (Online Today, 1989: 1-20).

Air Force Civil Engineering recognized the importance of computers in the management of information in the early 1980s. As a result, the WANG-based Work Information Management System (WIMS) was developed (Wentland, 1989). As stated in the BCE's Guide to WIMS, "Information is power. Through visibility of information...WIMS improves customer service, enhances control of resources and allows information sharing." (BCE's Guide, 1988:1). Although not currently utilized in a construction management lessons-learned capacity, "the WANG is fully capable of handling such a task if the user's requirements were defined in this area" (Wentland, 1989).

One of the most significant aspects of the success or failure of an MIS involves the human resource. According to Eldin Garrison, "It is difficult, in fact, to list any

cause of failure that does not have its origins in some kind of human interface with the machine." (Garrison, 1980: 15).

From a Civil Engineering viewpoint, a construction management lessons-learned MIS must meet the needs of the construction manager. For a Civil Engineering construction manager, the best user interface for a lessons-learned management information system would be a computer system common to all CE units. This would have to be the WANG-based minicomputer system, currently integrated in almost all Civil Engineering squadrons Air Force wide (BCE's Guide, 1988: 1-23).

Summary

Civil Engineering construction managers are frequently young and inexperienced. As a profession, construction management relies heavily on experience to successfully complete large and complex construction projects. One way AF construction managers can expand their experience base is through the use of lessons-learned, i.e. the positive and negative experiences of others. The AFRCEs, responsible for the management of large scale MCP construction, all agree better use of lessons-learned offers tremendous benefits in AF construction management. Although many lessons-learned are documented, they are usually accessible only to the original authors, or are filed away never to be seen again. Management information systems are ideally suited to this type of information sharing problem. This research

establishes a methodology for the development of an on-line, WANG computer based lessons-learned management information system for the use of AF construction managers; and, the characteristics of what a user-developed prototype would be.

Chapter II presents a detailed look at past research in the area of management information systems and lessons-learned databases. Chapter III provides the methodology used in this study to solve the research problem. Chapters IV and V present the research findings and Chapter VI draws final conclusions and offers recommendations for further research.

II. Methodology

Overview

Meeting the research objectives required collection of primary data. Although the literature provided a firm understanding of the important factors and techniques of MIS development, it lacked substance in three major areas: a) How do other lessons-learned MIS's operate? b) How should a lessons-learned MIS be implemented on the Air Force CE WANG mini-computer? and, c) How would the users of the proposed MIS structure the system? This void in the research knowledge was filled through the use of surveys and direct observation. Direct observation was very helpful in learning how other MIS's operate. Surveys provided the answers to how an MIS is implemented on the WANG and how the users would structure the proposed MIS.

As outlined in William C. Emory's Business Research Methods, surveys can be either interviews or questionnaires depending upon the survey strategy (Emory, 1985: 202). The primary data for this research was collected via a combination of personal interviews, telephone interviews and electronic mail. These methods were used in lieu of written questionnaires based on the need to approach the data gathering process in an exploratory fashion. Additionally, personal interviews, or telephone interviews offer the researcher much more latitude when dealing with exploratory research of a complex subject (Emory, 1985: 203).

Population and Sample

The population of interest for this research consisted of all Air Force major construction program managers, and all lessons-learned management information systems. However, since no statistical inferences were to be made on the data, and there was no need to generalize to a population parameter, a nonprobability purposive judgement sample was considered adequate for the exploratory research desired. Consequently, a sample consisting only of the construction program managers at major AFRCEs was deemed sufficient to establish the user's requirements. Similarly, a sample consisting of major DOD lessons-learned systems was considered adequate. Data for this research was collected from HQ USAF Installation Development Division (LEED), Washington D.C.; the Air Force Engineering and Services Center (HQ AFESC), Tyndall AFB, FL; HQ AFLC Systems Management Office, Wright Patterson AFB, OH; HQ AFLC Directorate of Engineering (HQ AFLC/DER), Wright Patterson AFB, OH; the Eastern, Western, Central and SAC Air Force Regional Civil Engineers (AFRCEs) and the Naval Air Test Center, Rotary Wing Division, Patuxent River Naval Air Station, MD.

The data obtained are not intended to be statistical, nor are the data to be taken as representative of Air Force wide construction program managers' requirements. A cross sectional study is adequate for the needs of the research, because it provides a simple snapshot in time of the users'

requirements for the proposed MIS. The designers and operators of every MIS researched stressed that a lessons-learned MIS is a "very dynamic, continually evolving" entity, which must have sufficient flexibility to adapt to the changing needs of the user (Grimsley and others, 1989). Based on this consensus, the data provided by this snapshot in time is adequate to initiate a lessons- learned MIS prototype, with the full expectation that the prototype will, by design, be changed and modified by the users.

The qualitative nature of the selected methodology was driven by the goal of the research -- to identify the subjective user's needs -- to aide in the development of a lessons-learned MIS. Quantitative research was ruled out because the opinions, ideas and free-thinking concepts desired are not quantitative data (Davis, 1988).

Collection of Data

Preliminary interview questions were developed based on information gained in the literature review and direct observation of several on-line systems. On-line systems observed included the Air Force Lessons-Learned Database, Naval Aviation Lessons-Learned Database, Reliability and Maintainability Checklist System, and other general information sharing systems such as the Lunar and Planetary Institute System, NOAA National Meteorological Database System and the BIONET System.

The majority of the questions were intentionally open ended to allow the respondents the opportunity to bring out additional information. Although the preliminary questions were reviewed by AFIT staff to ensure face validity and reliability, as was anticipated, several respondents surfaced additional facets of the WANG and MIS questions that were beneficial to the research. For this type of exploratory research, open, semi-structured questions are highly recommended (Emory, 1985: 203).

An additional motivation to use interviews in lieu of written questionnaires was the geographic closeness of several sources. HQ AFLC/DER, in charge of several large-scale construction projects, offered much insight from a user's perspective of the proposed management information system. HQ AFALC/LSL provided significant insight into the concept of USAF lessons-learned databases. All of the organizations noted are located on Wright Patterson AFB, collocated with AFIT and the researcher.

Due to limited travel funds, HQ Air Force Engineering and Services Center (HQ AFESC) at Tyndall AFB, and the Naval Air Test Center, Rotary Wing Division (NATC) at the Patuxent River Naval Air Station were selected as the most important distant location requiring personal interviews. HQ AFESC is the initiator and office of primary responsibility for the Civil Engineering WANG computer system. Personnel at HQ AFESC were instrumental in the determination of a MIS structure best suited for integration on the WANG and use by

Civil Engineering construction managers. HQ AFESC personnel also explained how application for the WANG system are typically developed. Personnel operating the Naval Aviation Lessons-Learned database system also provided significant insight into the development of DOD on-line lessons-learned systems.

Telephone interviews were conducted with the AFRCEs to formulate the underlying user's requirements data needed. Although personal interviews may have yielded additional data, the cost of travel outweighed the limited additional benefits of more data. The use of interviews, both personal and telephone, does require more time than other survey techniques. Many more users could have been reached in an equivalent amount of time if a written questionnaire approach had been chosen. The use of written questionnaires was rejected, because the goal of the research was to gather new ideas. Interviewing offers the best means of accomplishing gathering new ideas (Davis, 1988). Also, the depth and breadth of information obtained through interviews far exceeds that gained through written questionnaires (Emory, 1985: 160).

Summary

A review of books, periodicals and journals answered the first research question, "How are generic management information systems developed?" With this background understanding, more focused research answered the second and

third research questions, "What lessons-learned management information systems are in use; and, how were they developed?" and "What common factors made the existing systems successful or less than successful?". The research of these questions involved 1) the review of additional literature including operating instructions, user's guides, preparation guides and assorted system specific documents, 2) personal and telephone interviews with the developers and operators of several systems, and 3) direct use and observation of the systems. Finally, answering the remaining research questions, "How should a WANG-based lessons-learned system be developed?" and "From the user's perspective, how should the WANG lessons-learned MIS be structured?" required personal and telephone interviews with Civil Engineering WANG systems personnel and AFRCE construction managers.

The final products of this research are 1) a generic methodology that should be followed when attempting to initiate a lessons-learned MIS on the WANG system and 2) a specific description of system characteristics, interfaces and functional relationships desired by AF construction managers. These products are provided in Chapters 4 and 5.

III. Literature Review

Overview

Every study is a search for information (Emory, 1985:135). In this study, the search is for information about the general area of information sharing through the use of management information systems and the specific area of on-line lessons-learned databanks. More confidence can be placed in quality of the findings of a study if all sources relevant to the subject have been explored (Emory, 1985:135).

To increase the confidence in the findings of this study, this chapter provides a review of previous studies and available techniques relevant to solving the research objectives. The structure of this chapter is from the broad area of generic management information systems and on-line information sharing to the focused areas of MIS development methodologies, and a review of what the DOD is doing in the area of lessons-learned. With the knowledge gained in the broad subject review, and the specific strengths and weaknesses learned in the focused area review, a clearer identification of the problem and variables involved was accomplished.

Previous Studies

Management Information Systems. From a very broad perspective, "a system is simply a set of components that

interact to accomplish some purpose" (Senn, 1984:11). A management information system (MIS) then, is a set of components that provide information to management. These components can range from a simple organized set of documents to a sophisticated computer system accessible to not only the organization owning the management information system, but also entities external to the owning organization (Senn, 1984: Ch1).

The use of the term "information" in defining or describing MIS is what distinguishes information systems from simple computers or software programs (Lucas, 1986: 10). Generally speaking, computers and their associated software programs process raw data and then output that same data in another form (Norton, 1986: 10-15). The difference between information and data is in the user's perspective. Information is raw data that has been processed in some way to allow action by the user (Lucas, 1986: 11).

An example of this distinction can be seen in considering a typical telephone book. If the names and numbers in a telephone book were listed in a random fashion, they would be considered raw data. However, once alphabetized and sorted by city and state, the raw data becomes information because it allows action on the part of the user (the user can now call a specific person). Lucas provides a schematic representation of an information system similar to that shown in Figure 3.

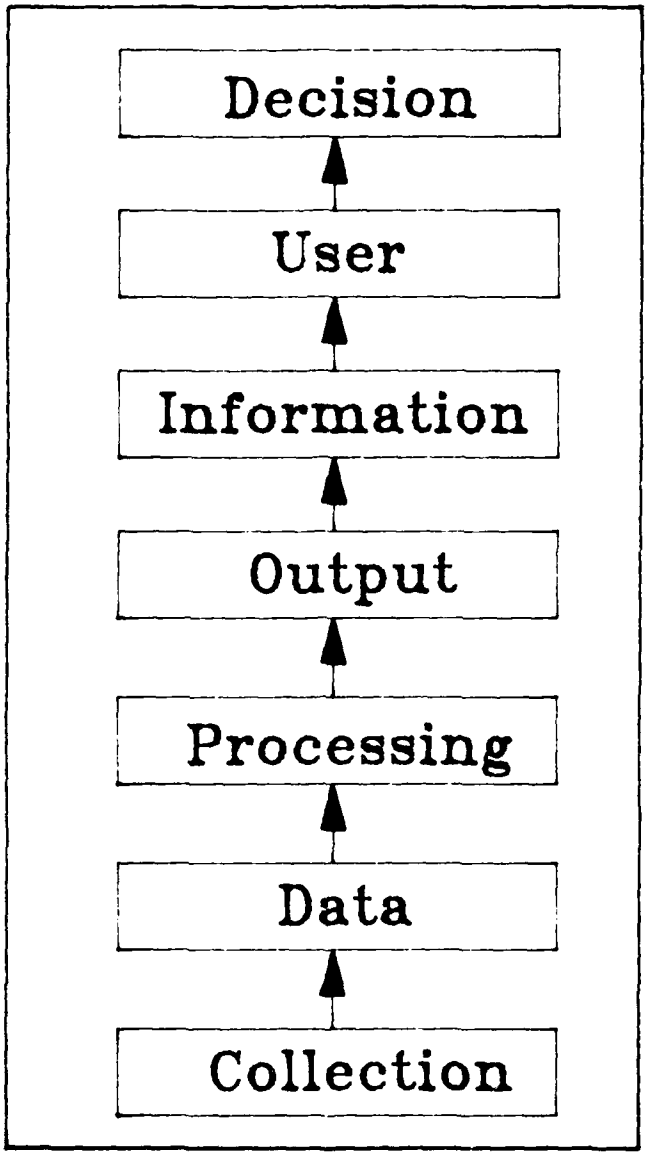


Figure 3. Schematic Representation of an Information System (Lucas, 1986: 11)

The definition of an MIS adopted here encompasses a broad area of data processing. For this reason, the definition of management information systems will be further narrowed by taking a look at the concept of information.

Information - Differing Systems and Needs. From the schematic representation of an MIS shown in Figure 3, the ultimate use of an MIS is to provide information to the user which will allow decision-making processes to occur (Lucas, 1986:11). Decision making processes at various organizational levels have distinctly different information needs. In order to meet these differing needs, each level has evolved its own type of information delivery tools (Powers and others, 1984: 9-10).

As stated by Lucas, "For most organizations - in the future, if not already - the determining factor in competition will be the processing and analysis of information" (Lucas, 1986: 5). Senn describes information systems as "pervasive" entities depended upon to some degree by all organizations. Further, information systems link an organization together "in such a way they can effectively work toward the same purpose" (Senn, 1984: 11).

The lowest level of information needs allows control over an organization's routine activities and transactions. This information need is fulfilled through Electronic Data Processing (EDP). Essentially nothing more than an automation of existing paperwork procedures, the basic features of EDP stress a focus on data storage and retrieval at the operational level and an efficient transaction processing system. It is generally agreed that EDP supports the lowest functional levels of an organization. However,

EDP does provide the essential information data base for all the higher level information systems (Curtis, 1985: 20).

The second tier of information needs in an organization is the ability to quickly review daily transactions and highlight problem areas or trends needing management attention. It is this level of information needs that management information systems were developed to support. According to Sprague and Carlson, MIS systems have a middle manager information focus, provide very structured information flows, and allow inquiry and report generation with EDP data bases (Sprague and Carlson, 1982: 7).

Higher levels of information needs in organizations also exist, for example information needed to set and achieve long range strategic goals (Curtis, 1985: 20). These information needs are met by Decision Support (DSS) and Expert Systems. Decision Support Systems focus on the informational needs of the highest levels of an organization. DSS utilize the results of EDP and MIS and may include additional data brought in from external sources. Decision support systems are structured as interactive, computer-based programs to help decision makers solve infrequent, unstructured problems (Curtis, 1985:21).

The next step of providing information to users above DSS would be to actually provide not only the information necessary to make the decision, but the decision itself. This is precisely what expert systems were designed to provide. Expert systems have traditionally been defined as

interactive computer programs incorporating judgement, experience, rules of thumb, intuition, and other expertise to provide knowledgeable advice about a variety of tasks (Maher, 1987:3).

According to Harris-Stewart, "expert systems are considered the most practical application of artificial intelligence to date." Artificial intelligence is the substitution of computers to yield the knowledge and expertise normally obtained from human beings (Harris-Stewart, 1988:32). According to Maher, expert systems are a result of many years of attempting to simulate or reproduce intelligent problem solving behavior in a computer program (Maher, 1987:3). The classic definition of an expert system is a computer program that, given a certain set of information, will yield the same solution, recommendation, or answer that a human expert would provide, given the same set of information (Riker and others, 1987:11).

Summarizing, EDP systems provide detailed data while management information systems provide selective information through further processing of the EDP data (Curtis, 1985: 19-23). With a firm understanding of a) exactly what an MIS is, and b) what level of information an MIS is designed to provide, consider how an MIS could be applied to the construction management problem.

MIS Development. There are many methods used in the development of MIS systems. The two most common approaches, and the ones that are considered here, are the traditional

and user-driven. Also addressed here is the concept of prototyping - a commonly used MIS development tool.

Traditional Approach. The traditional systems development life cycle consists of seven activities: 1) preliminary investigation, 2) requirements determination, 3) prototype development, 4) system design, 5) software development, 6) systems testing and 7) implementation (Senn, 1984: 18). Although several of these activities may happen concurrently, the traditional systems development cycle is often a very lengthy process (Wentland, 1989).

The traditional development approach saw the MIS designer asking the managers what information they would like to have. Unfortunately for the MIS designer, most managers did not really know what information was needed. This discovery frequently led to the failure of the developed MIS. In some cases executives with strong personalities did make firm statements about the information needed by their departments. Systems developed for these managers were usually highly personalized and almost never survived the departure of the user they were created for (Martin, 1984: 42).

The widespread use of computers created a growing demand for applications and a shortage of programmers to develop new systems. As a result, user-created applications are now being developed. Another more powerful reason driving user-developed systems is in many situations the conventional development process does not work. All too

frequently systems have been installed after years of development effort only to result in the end users saying it is not what they want. Even worse, in many instances the users try a system for a while and then give up because they wanted something different (Martin, 1984: 41). Martin further noted,

> A common reaction to this unfortunate situation is to say that the requirements were not specified sufficiently thoroughly. So more elaborate procedures have been devised for requirements specification, sometimes resulting in voluminous documentation. But still the system has been unsatisfactory. (Martin, 1984: 41)

Many organizations have made attempts at getting the application creation process working to the satisfaction of the users. Often, these attempts made the situation worse. Steps were often taken to enforce more formal procedures to convert the application creation process "from a sloppy ad hoc operation to one that follows rules like an engineering discipline" (Martin, 1984:42).

The DOD recognized it had problems due to the traditional software development process and mandated certain actions in response to them, in DOD Directive 5000.29, Management of Computer Resources in Major Defense Systems. DOD Directive 5000.29 attempted to reverse the trend of programs being created that did not meet the user's requirements. A Computer Resource Life Cycle Management Plan specified more formal requirements documentation prior to the design, coding, and testing. By formalizing the stages of systems development and requiring certain

milestones be attained and documented the DOD hoped to "ensure the proper sequence of analysis, design, implementation, integration, test deployment and maintenance" (Martin, 1984: 42). Within the DOD, and elsewhere, a strong push has been made to "get the user into the driver's seat of systems development" to improve the development process (Wentland, 1989).

Martin uses the terms "user-driven computing and prespecified computing" to explain the distinctions between the traditional approach and the user-driven approach to systems development. These distinctions are highlighted in Figure 4 below.

User-Driven Approach. The user-driven approach allows fast application creation because whenever possible, the end users create and modify their own applications. The use of "fourth generation" computer languages has made it possible to, in essence, use computer software to help write new software. These application generators have reduced systems development time to days or weeks. In other cases a system analyst using applications generators creates the new application working at a terminal in concert with the end user. The user-driven process is incremental and interactive, as the process uses prototypes to replace lengthy written requirements documents. If the prototype meets the user's needs it is often converted directly into the application (Martin, 1984: 41-43).

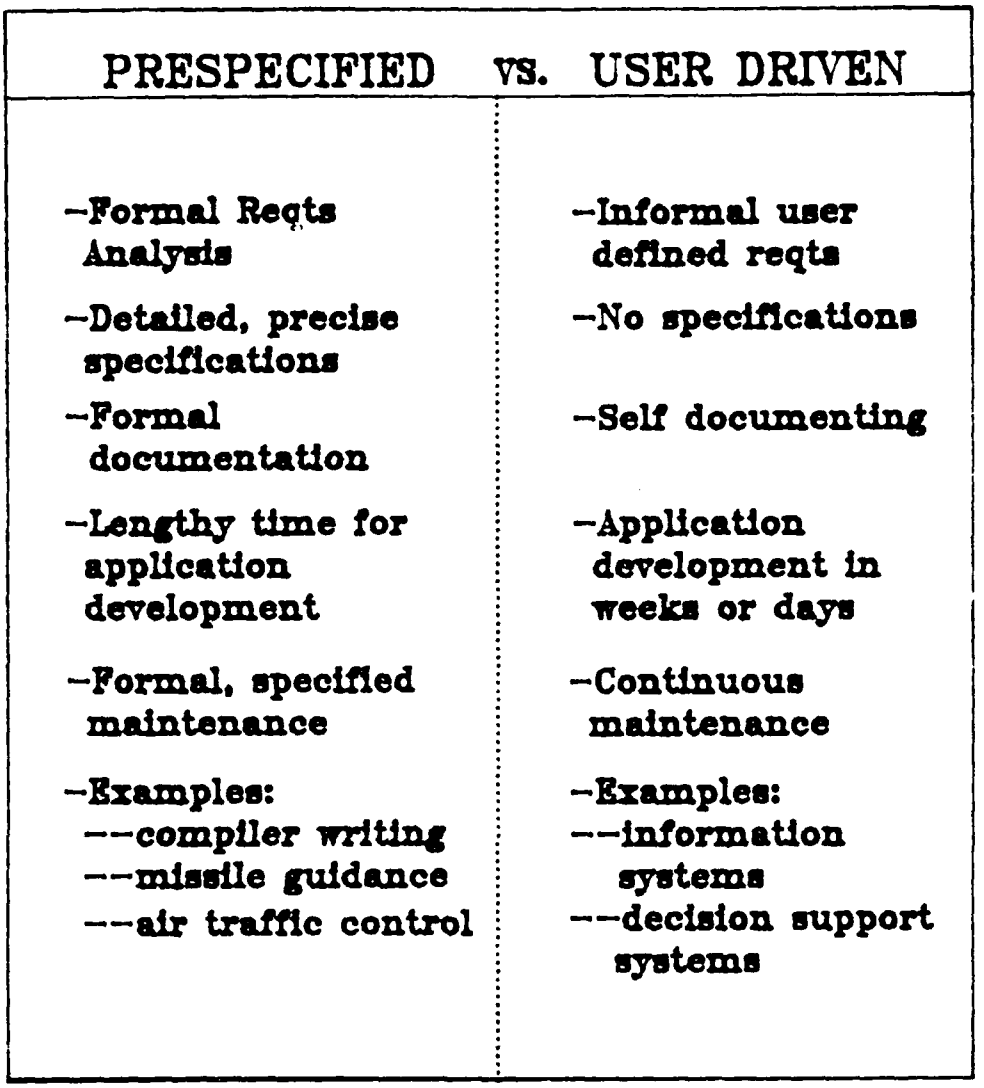


Figure 4. Systems Development Methodologies (Martin, 1984: 43-44)

The maintenance of user-driven systems is almost continuous as a result of the incremental change process used. Documentation of user-driven systems is self generating, as the application is created by the applications generator (Martin, 1984: 43-46). At its best, the user-driven approach is "very impressive compared with the traditional DP development cycle" (Martin, 1984: 41).

Decentralization of information systems away from large centrally located mainframes to the newly developed "small multi-user minicomputer systems and then to the single user microcomputers" aided the trend to user-driven application development (Lee, 1988: 17). In many instances,

> End users gained control of much of applications development, making the applications quicker to develop, reducing the applications development burden on the DP/MIS department, and greatly increasing end user job satisfaction. (Lee, 1988: 19)

On the negative side, there are problems with the user-driven systems approach. By nature, user-developed systems do not generally follow the rigorous development discipline seen in the traditionally developed systems. Consequently, data validation, audit trails, backup procedures and documentation are often lacking. DP/MIS departments and their information systems personnel should, as much as possible, become information systems consultants to the users to preclude these problems (Lee, 1988: 18).

Prototyping. Prototyping is a tool that can be used within either the traditional or user-driven development methodologies. According to Martin,

> The concept of prototyping is particularly important. With most complex engineering a prototype is created before the final product is built. This is done to test the principles, ensure that the system works and obtain design feedback which enable the design to be adjusted before the big money is spent. ... Complex data-processing systems need prototyping more than most engineering systems because there is much to learn from a pilot operation and many changes are likely to be made. (Martin, 1984: 46)

Until the 1980s the cost of programming a prototype was almost equivalent to the cost of programming the live working system. The 1980's brought fourth generation computer languages that enabled prototypes to be created cheaply and quickly (Kraushaar and Shirland, 1985: 189). Additionally, packaged software programs allowed the user to experiment and try different methods of data-base queries, report generation, and manipulation of screen information (Martin, 1984: 44).

An Application of MIS

The problem addressed in this research could be reduced to one of information availability. Specifically, many US Air Force construction managers are inexperienced and unable to easily draw on the experiences of others in their field. Using the schematic representation of the various components of an MIS (shown in Figure 3) as an outline, the applicability of a management information system to this problem was explored.

Data. The data that is needed for this MIS consists of both technical and managerial "lessons-learned" in construction management. These "lessons-learned" could be something as simple as "avoid the use of flat paint on handrails and stair casings because it collects dirt easily and is difficult to maintain", or something as complex as "the use of an asphaltic waterproofing membrane between the mudslab and structural concrete sections on an inclined

surface requires bracing the structural sections against in situ material to prevent slippage. This is required because the asphaltic membrane, under pressure, loses viscosity and acts as a lubricant". This latter example actually occurred at three different, large scale construction sites in Saudi Arabia because the "lessons-learned" at one site were not readily available to the other sites (Meister, 1989). Although the examples given here are primarily technical in nature, management lessons-learned are also applicable to the problem and could be input into the MIS. Management lessons address program decisions, budget and financial matters, contracting techniques, maintenance concepts and data management (Schmidt, Undated: ii)

Data Collection. Air Force Regulation 89-1, requires construction managers to "identify positive or negative lessons-learned" during facility construction. AFR 89-1 also directs that Post-Occupancy evaluations be accomplished 9 to 11 months after construction completion to identify additional lessons-learned (AFR 89-1, 1978: 4.5). The primary source of this data would be Air Force Regional Civil Engineers (AFRCE).

Processing. Processing of data into a usable format would require the use of some form of organization to allow rapid retrieval by subject, engineering discipline, key words, and many other potential inquiry formats. A computer based management information system to store and retrieve the data could handle the expected explosion of information

and quickly process the large amounts of data involved (Lucas, 1986: 11).

Output, Information and the User. The output, information and user subprocess areas of an MIS are combined here to emphasize the interaction between the three elements.

> Perhaps the most significant aspects of MIS failure involve the human resource. It is, difficult in fact, to list any cause of failure that does not have its origins in some kind of human interface with the machine.
> (Garrison, 1980: 15)

The importance of Garrison's statement is underscored when it is recalled that information is determined from the user's perspective (Lucas, 1986: 11). If the output does not provide information to the user, the MIS will fail (Garrison, 1980: 12). In the construction management MIS example, the form of the output must be determined by the construction managers who are relying on the system for information.

Decision. The final subprocess area of an MIS, the decision, hinges on the value of the information provided. Information has key characteristics including time frame, expectation value, scope, source, frequency, organization and accuracy (Lucas, 1986, 31). For construction managers using the proposed MIS, all of these attributes of information will play a factor in whether or not the information provided affects the decisions required in their job. If the information is accurate, timely, organized, and

adequately scoped, it will affect their decision and hopefully provide the information they once lacked due to limited construction experience.

Summary

Management information systems provide information to management. Seven subareas of an MIS are data, collection, processing, output, information, user and decision. Working together these MIS subareas highlight problem areas or trends needing management attention. Other levels of organizational informational needs are met through electronic data processing, decision support systems and expert systems.

Two common approaches to the development of MIS systems are the traditional and user-driven methods. The traditional systems development cycle consists of seven activities: 1) preliminary investigation, 2) requirements determination, 3) prototype development, 4) system design, 5) software development, 6) systems testing and 7) implementation. The advent of fourth generation computer languages, and problems inherent in the traditional approach, have led systems development away from the traditional approach and towards the user-driven approach. The user-driven approach is less structured, quicker and more apt to result in a system that meets the user's needs than the traditional development approach. With the user-driven approach, the end users often create and modify their

own applications either with or without the assistance of a systems analyst. Prototyping is a tool used in both the user-driven and traditional MIS development approaches. Regardless which development methodology is used, management information systems are well suited to the basic information sharing problem of AF construction managers needing access to the lessons-learned by others.

Having considered the basics of management information systems, and typical MIS development methodologies - the next chapter reviews existing information systems, both general and in the specific area of lessons-learned.

IV. Findings Related to Existing Systems

Overview

In addition to the information gained from the literature review, significant insight into information systems was obtained by using several existing systems firsthand and/or talking to the systems operators. This chapter outlines several of the systems investigated. The selection of systems to review began with general information systems and progressed to lessons-learned systems. The degree of detail provided in this chapter for general systems is, by intent, less than that provided for the lessons-learned systems.

General Information Systems

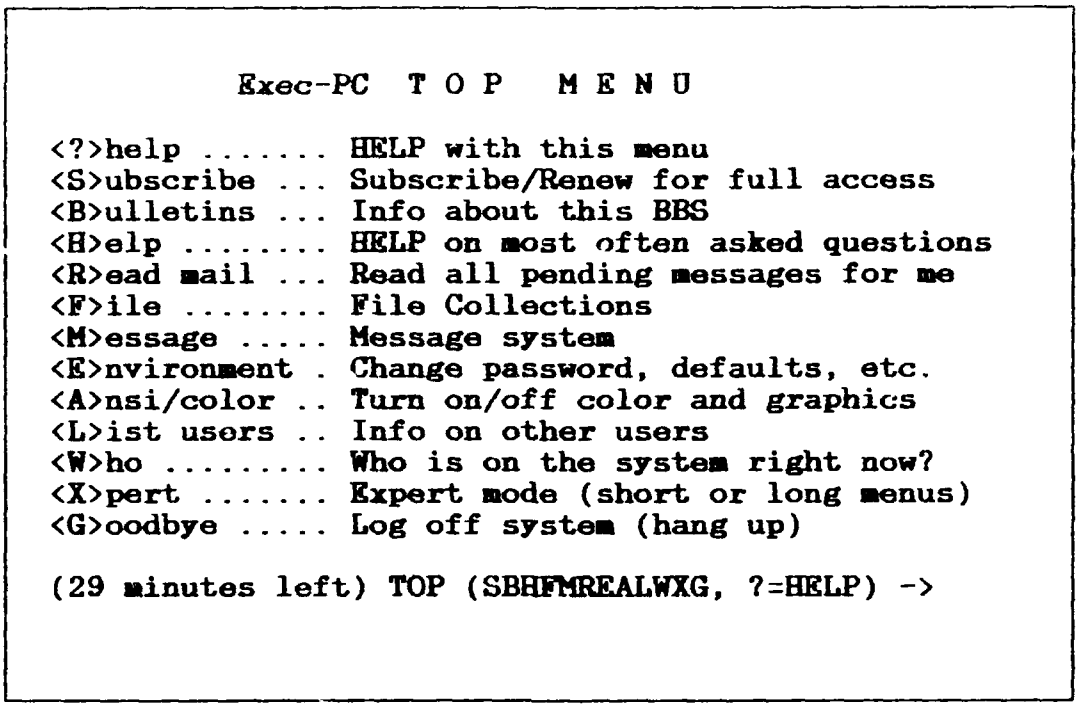
Electronic Bulletin Boards. The proliferation of personal computers (PC) brought with it the proliferation of electronic bulletin board systems (BBS). PC based BBSs are relatively low cost systems for information sharing because they can be set up on any personal computer with a hard disk and modem. A typical bulletin board consists of a PC, one or more modems, data and a software application to control the use of that data by remote users. The owner of the PC or BBS is usually the systems operator (SYSOP). The SYSOP keeps the bulletin board operational, provides help to new users, and generally controls what the bulletin board is used for. Remote users, through their PC and modem, can

connect to the bulletin board via telephone and have access to whatever information is on the BBS. Most BBS' function as a place to trade computer programs, play games, or in general, share information with other remote users (Grimsley, 1989). Several bulletin boards were explored, the one that is detailed here, Exec-PC BBS Network, is fairly representative of this type of information system.

Exec-PC. The Exec-PC BBS Network is for IBM-PC and Compatibles, UNIX/XENIX Apple Macintosh, Commodore Amiga, and Atari ST computers. Extensive information, programs and files for these computers are available on the Exec-PC BBS. Since its inception in 1982, Exec-PC has had almost two million callers. Exec-PC is used by more than 2,000 callers per day searching for free software or message system activity related to their interests (Exec-PC, 1989).

One typical problem of BBSs is access. Users often can not log onto a BBS because the phone lines are busy. Exec-PC has nearly eliminated busy signals by using over 90 phone lines. Although actually a very large system, Exec-PC is very user-friendly. Easy, self explanatory, direct menus with full graphics capability using color and graphics to guide your eye makes Exec-PC simple to understand and use. Exec-PC's interface is logical in its layout, as shown by the Exec-PC main menu in Figure 5 (Exec-PC, 1989).

Exec-PC allows 2 levels of access. Free access gives limited use of the system, paid access gives full use of the system. Full paid access allows the user 420 minutes of



BBS log-on time per week and/or a download limit of four megabytes (4,000,000) of files per week. Additionally, full access users can send messages to anyone in all conference/topics areas, send and receive private email to/from anyone, read all messages in all public conferences, download files from all file collections, and upload files to all collections in which upload is an option. Users who don't pay to join Exec-PC are limited to 30 minutes per day access time, during which they may send/read messages to/from the SYSOP, read all messages in the MS-DOS conference and download up to 360,000 bytes/day from the free file collections. Exec-PC rates are $20 for 3 months full access or $60 for one year full access (Exec-PC, 1989).

As noted by the opening bulletins, Exec-PC supports,

> Ninety incoming phone lines, 24 hours per day. All lines have 2400 baud modems with MNP error correction. USR HST dual standard 14,400 baud & V.32 modems on some lines. Over 70,000 total files collected in the Mahoney and PC-SIG systems, plus a 4,200 megabyte (4.2 gigabyte) high speed mass storage system. Numerous message conferences and topics supported by an advanced software system. (Exec-PC, 1989)

In addition to the features noted, Exec-PC uses the Hyperscan(tm) file search feature, capable of searching 20,000 file entries in less than 2 seconds. Exec-PC users also have direct connect to the Telenet(tm) nationwide data network (Exec-PC, 1989). These and other features combined make Exec-PC a very useful information sharing tool.

Research Systems. There are many on-line information systems designed to aide research in scientific and technical areas. Some provide access to a broad spectrum of research areas, others are designed to support one specific area of research. One of the largest research oriented information systems is the Defense Research Development Test and Evaluation On-Line System (DROLS) operated by the Defense Technical Information Center (DTIC).

DROLS System. The DROLS system is the on line portion of the Defense Technical Information Center. The mission of DTIC is to further Department of Defense research and development (R&D) efforts by increasing the access and transfer of scientific and technical information applicable to defense R&D. DROLS is one tool DTIC uses to meet this mission. DROLS has access to over 1.2 million technical

reports, notes and memoranda contained in four separate databases (Taylor, 1989).

DROLS data is obtained through the principle users of DROLS - DOD agencies, DOD contractors, government agencies, educational institutions and foreign agencies and institutions. Users of DROLS may access the on-line databases using either a personal computer and modem or UNIVAC terminals hard-wired to DTIC's central computer system. Classified information is only accessible using dedicated phone lines and hard-wired terminals (DTIC, 1985).

DROLS has been on-line since 1968 and is hosted on a Sperry/Univac (UNISYS) computer system. There are 1080 users of DROLS; however, a single DROLS user is most often an agency or institution (such as the AFIT library) that performs DROLS searches for many people (Taylor, 1989). DROLS users can search the databases for information based on author, source, report date, title or subject. DROLS supports text searching of the title and report narrative on a limited basis (DTIC, 1985).

Because of the costs associated with connection to DROLS ($30 per connect hour), on-line research of the DROLS was very limited. However, other research oriented systems were researched intensively. Specifically, the Lunar and Planetary Institute's PATRON System, US Department of Agriculture's BIONET System and the National Oceanic and Atmospheric Administration's Meteorological Database System,

were researched. Of these systems, the PATRON and BIONET are also presented here.

PATRON System. The Lunar and Planetary Institute (LPI) in Houston Texas, operates an on-line information system, PATRON, to make the space research material in their library information center more accessible to more people. The PATRON System offers on-line access to all basic library functions such as bibliographical searches, card catalog searches, reference material ordering, etc. PATRON provides access to the library when a staff member is not available (after hours & weekends) or from a remote location. Through PATRON new users can also learn about the library information center and the various services that are offered, quickly and easily. The primary functions of PATRON can be realized by looking at PATRON's main menu, shown in Figure 6 (PATRON, 1989).

According to Stephen Tellier, responsible for the development and initiation of the PATRON system, PATRON is hosted on a VAX/1170 computer at the Institute. PATRON is accessible via direct connect terminals or remote terminals via modem at 300/1200/2400 BAUD transmission rates. PATRON is a menu driven system, but the menus can be disabled by users who prefer to operate in a command driven mode. The PATRON on-line help facilities make using the system very easy. PATRON has seen a 200 percent increase in usage in two years and is now averaging over 1000 calls per year. The Lunar and Planetary Institute is now on the Space

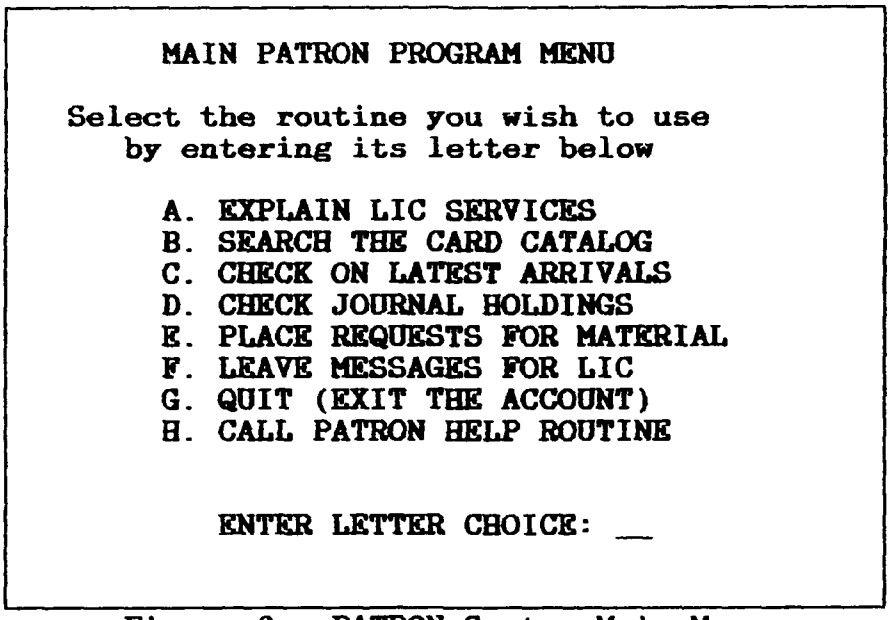


Figure 6. PATRON System Main Menu (PATRON, 1989)

Physics Analysis Network (SPAN) and an additional increase in users is expected. Users of the patron system who also have access to SPAN may use it to connect with other LPI on-line services (Tellier, 1989).

BIONET System. The Biology Network (BIONET) System is an on-line molecular biology databank for scientists and researchers. BIONET is a menu-driven system open to all non-profit organizations associated with USDA Agricultural Research Services (ARS). Through BIONET, researchers and scientists investigating DNA/RNA sequencing and protein and nucleic acid sequencing can quickly access the work of others in their field to determine whether particular sequences are new or merely a match to known sequences. BIONET provides an avenue where researchers working with cloning, DNA/RNA sequences, disease analysis

or any of the many fields in plant or animal molecular biology areas can share their findings and increase technology transfer within the field (Laster, 1989).

BIONET users can also access the US National Institute of Health's (NIH) Genetics Databank and the Molecular Biology Laboratory's Databank in Heidelburg, Germany. BIONET is established in Beltsville Maryland as a USDA satellite installation through a cooperative agreement between the National Institute of Health and the Intelligenetics Corporation of Palto Alto, California (Laster, 1989).

Lessons-Learned Management Information Systems

In the specific area of lessons-learned, several management information systems have been developed and are in use today. These lessons-learned MISs range from manual systems used by individual organizations to computer-based, service-wide systems. Each management information system has individual strengths and weaknesses that contribute to its respective success or failure. Two of the largest DOD lessons-learned management information systems - the Navy's Naval Acquisition Lessons-Learned system and the Air Force's On-Line Access Lessons-Learned system were explored. The U.S. Army Research and Development Center maintains a series of lessons-learned reports available in hard-copy format (Booker, 1989). Although in the process of developing an on-line lessons-learned system, the Army does not currently have an on-line lessons-learned system (Grimsley, 1989).

Naval Aviation Lessons-Learned Database. In 1982 the Naval Air Systems Command (NAVAIRSYSCOM) initiated a lessons-learned program to support the Joint Services Advanced Vertical Lift V-22 "Osprey" aircraft acquisition. The Naval Aviation Lessons-Learned (NALL) system is the result of that effort (Gardiner, 1989). As outlined in the Naval Aviation Lessons-Learned Program Management Plan, the goals of the NALL are to "reduce procurement and life cycle costs, improve reliability and maintainability, and improve readiness by learning from past experiences" (Naval Aviation Lessons-Learned Program Management Plan, 1986:1).

History. The lessons-learned concept was sponsored through a tri-service agreement between the Joint Logistics Commanders (JLC) of the Army Material Command, Chief of Naval Operations, Air Force Systems Command and Air Force Logistics Command (NALL Preparation Guide, 1989: 3). Although, no longer within the JLC arena, the NALL continues to operate under a tri-service memorandum of agreement (Naval Aviation Lessons-Learned Program Management Plan, 1986: 2). The tri-service memorandum of agreement, effective 15 March 1989, serves as the implementation directive through which lessons-learned exchange procedures are established (Grimsley, 1989).

The initiation of the NALL began with the collection of lessons from a variety of sources including the Army and Air Force. A lessons-learned team also interviewed managers, supervisors, operators, and maintenance personnel through a

series of visits to fleet operating and support activities. These interviews concentrated on both positive and negative information about the supportability, maintainability, and reliability factors of current weapon systems. The material collected was then evaluated and developed into potential lessons-learned (NALL Preparation Guide, 1983: 1-2).

The resultant lessons-learned were input into a computer database beginning in 1983 and completed in 1984. The initial database of lessons-learned was less helpful than originally envisioned, primarily due to the difficulty experienced by users attempting retrieval of the lessons-learned (Grimsley, 1989). This early version of the automated NALL was extremely "user-unfriendly", provided minimal information through a series of one-page reports, and was severely limited in lessons-learned manipulation and extract capabilities (Grimsley, 1989).

Configured as a series of "quick and dirty batch programs", written with limited input from the user, the early NALL system did not meet the needs of the user (Dove, 1989). Consequently, the early NALL was infrequently used and program interest "died for a period of six to eight months" (Grimsley, 1989).

Upon recognition that the original NALL database was of limited usefulness, a revised NALL system was considered to overcome the weaknesses cited. Through extensive interaction and communications between the NALL users and system programmers, the on-line NALL database and user

interface was restructured to its current configuration (Dove, 1989). The current NALL system has over 200 users compared to the original system's 15 users. Despite this increase in usage, computer costs associated with the system have decreased. The NALL operators attribute this drop in cost to the NALL's increased user-friendliness and the users resultant ability to quickly find and extract only the information they need (Grimsley, 1989).

One potential measure of the current NALL system's success is the revived interest in the program, as witnessed by the increased usage. Additionally, several contractors such as McDonnell Douglas, Boeing, Hughes Aircraft, General Dynamics and others have either initiated their own lessons-learned system or requested installation of the NALL on their company computers (Grimsley, 1989).

System Configuration. The NALL database is installed on an IBM Amdahl 470VA mainframe computer located in the Computer Sciences Directorate at the Naval Air Test Center, Patuxent River, MD. The on-line system operates under the Multiple Virtual System (MVS), Time Sharing Option (TSO), and System 2000 Database Management System software (NALL User's Guide, 1989. 6).

The NALL can be accessed through any terminal directly tied to the Amdahl mainframe. Alternatively the NALL is accessible to remote users possessing a user-id and password provided by the Naval Air Test Center upon request. Remote users must have an IBM personal computer or equivalent, with

a modem and at least one floppy disk drive and a hard drive. Prior to accessing the system, remote users must install the NALL Remote User's Software provided by the Naval Aviation Lessons-Learned Office. The NALL is available for access 24 hours per day, seven days per week. (NALL User's Guide, 1989: 4-5).

NALL Database Configuration. The NALL database currently contains 1298 lessons (Dove, 1989). Each lesson contains the ten different sections listed and explained below:

1. NATC CALL NUMBER: Internal tracking number unique to each lesson learned.

2. ACCESS NUMBER: Assigned by the Lessons-Learned Research Team for tracking and referencing during validation.

3. IMPACT AREAS: A listing of up to six major areas that the lesson affects, for example: safety, engineering, facilities, human factors, health, training, reliability, survivability, etc. There are 44 total impact areas.

4. TOPIC: Title/subject of the lesson learned, brief but representative of the content of the lesson.

5. LESSON LEARNED: The actual lesson learned, its cause and its effect.

6. PROBLEM: Descriptive statement of what went wrong. If the lesson is positive, this area says "NONE".

7. DISCUSSION: Summary of the lesson learned research findings conducted to validate the lesson.

8. APPROPRIATE ACTION: Recommendation(s) on possible ways to avoid the problem.

9. WORK UNIT CODE (WUC): A two-digit code used to identify the specific system or type of equipment affected by the lesson. Over 100 codes are available in the Standard Work Unit Code Manual, however only up to five are used on each lesson. WUC examples include: helicopter rotor system, landing gear, support equipment, simulators, power systems, utilities, etc.

10. AIRCRAFT TYPE: A two-letter code denoting the type of aircraft affected, such as rotary wing, fixed wing, fighter, etc. This code is applied only if the lesson applies only to that type of aircraft. If the lesson is applicable to all aircraft or non-aircraft support equipment then the codes AA or SE, respectively, are used.

By agreement between the Joint Logistics Commanders, the call number, topic, lessons-learned, problem, discussion and appropriate action sections constitute "the minimum standard format for documenting individual lessons-learned within and among the Services" (Joint Agreement on the JLC Lessons-Learned, 1989: 1-2).

For purposes of readability and conciseness, typical NALL lessons-learned are no more than one typed page long. One of the principle concepts behind lessons-learned is simplicity. Lessons are, and should be, written in plain English with minimal use of jargon and technical terminology (Gardiner, 1989).

The primary emphasis of the NALL is lessons-learned in the acquisition of Naval aviations systems or aircraft, hence, lessons-learned in construction or facility acquisition are not directly supported. For example, designators such as "work unit code" and "aircraft type" are not appropriate for facility construction lessons. Although the NALL does not directly support construction lessons, the application of the concept of construction lessons-learned is valid. The Navy projects its power through ships, not airfields and facilities - hence, Navy facilities receive less emphasis than Air Force facilities (Grimsley, 1989).

A transcription of a sample lesson retrieved from the NALL is shown in Figure 7 below:

CALL NUMBERS:	IMPACT AREA(S):
NATC 00271 ACCESS 88-793	Design Reliability Human Factors
TOPIC:	Helicopter transmission oil fill screens
LESSON LEARNED:	Lack of screens on helicopter transmission oil filler necks can result in foreign object damage to the transmission.
PROBLEM:	Foreign objects are being introduced into helicopter transmissions during oil servicing.
DISCUSSION:	Some helicopter transmissions do not have screens in the oil filler neck. Foreign objects such as the foil screens from oil containers have been introduced during servicing. Although use of servicing units incorporating in-line filters is required, unit unavailability or nonuse by servicing personnel exposes the oil system to possible introduction of foreign objects.
APPROP. ACTION:	A) Designers of helicopter transmissions should incorporate screens in the oil filler necks capable of preventing entry of foreign objects during servicing. B) Specifications for transmissions and gearboxes should require fod screens on oil servicing or filler openings. C) Consideration should be given to retrofit filler necks lacking screens. D) Increased emphasis must be placed on training to ensure proper servicing.
WUC:	15 AG AP AX

Figure 7. Sample NALL Lesson
(NALL, 1989)

Data Input. Potential lessons-learned for the NALL are obtained from a variety of sources including successful or unsuccessful acquisition program experiences, personal experiences, test reports, inspection deficiencies, safety mishap data, maintenance data, engineering data and contractors. Virtually anyone who has experience in naval aviation weapons systems design, acquisition, operation or maintenance is considered a source for lessons-learned (Grimsley, 1989).

Potential lessons-learned are submitted to the Naval Air Test Center, Rotary Wing Aircraft Test Directorate (RWATD) for research and validation. The primary input of potential lessons is accomplished by an in-house staff of researchers who have set up contacts with field units and contractors. Additionally the research staff monitors a flow of written communications (safety reports, naval message traffic, readiness summaries, etc) and looks for repetitive trends or an inordinate amount of communications on positive and/or negative experiences (Naval Aviation Lessons-Learned Preparation Guide, 1989: 1-3). Other lessons-learned submissions are received through personal contact during lessons-learned staff visits to field units and contractors. Lastly, a recent source of input is the NALL bulletin board, to be discussed later (Grimsley, 1989).

Once a potential lesson learned has been identified and forwarded to RWATD, it is assigned to one of 8-10 staff researchers. The researcher contacts the individuals

involved with the potential lesson, reviews all pertinent technical data, and validates that the potential lesson is more than an opinion or result of failure to follow regulatory guidelines. Quality research is critical to the validation of lessons-learned. Accordingly, a potential lesson will not be researched in-depth or logged in until it is supported by two or more recognized sources (Naval Aviation Lessons-Learned Preparation Guide, 1989: 5-6).

Upon completion of the validation the researcher prepares a synopsis of the research and analysis in a lessons-learned format. It is the policy of the Navy to sanitize all lessons-learned such that neither the lesson nor the backup documentation attached contains any reference to the use of "specific type/model of aircraft/equipment, contractors, subcontractors, or vendors" (Naval Aviation Lessons-Learned Preparation Guide, 1989: 5-6). This policy is established both to preclude legal disputes and to encourage those involved in negative lessons not to be afraid of forwarding a lesson learned (Grimsley, 1989). After review and approval of the lesson by the NALL review board, comprised of NALL team members and fleet and field engineers, the approved lesson is entered into the NALL database (Naval Aviation Lessons-Learned Preparation Guide, 1989: 7).

Data Retrieval. The NALL system initiators made every attempt to ensure the NALL is user friendly. The NALL is a menu-driven system allowing the user to select which

activity is desired from a preset menu of options. Each menu is self-explanatory and the options available are clearly shown. The layout and options provided by each menu, and the program-level interface between submenus were established through close coordination between the users and system programmers (Dove, 1989).

The opening menu of the NALL system, shown in Figure 8 below, allows the user to select either a REPORTS or RETRIEVAL search method.

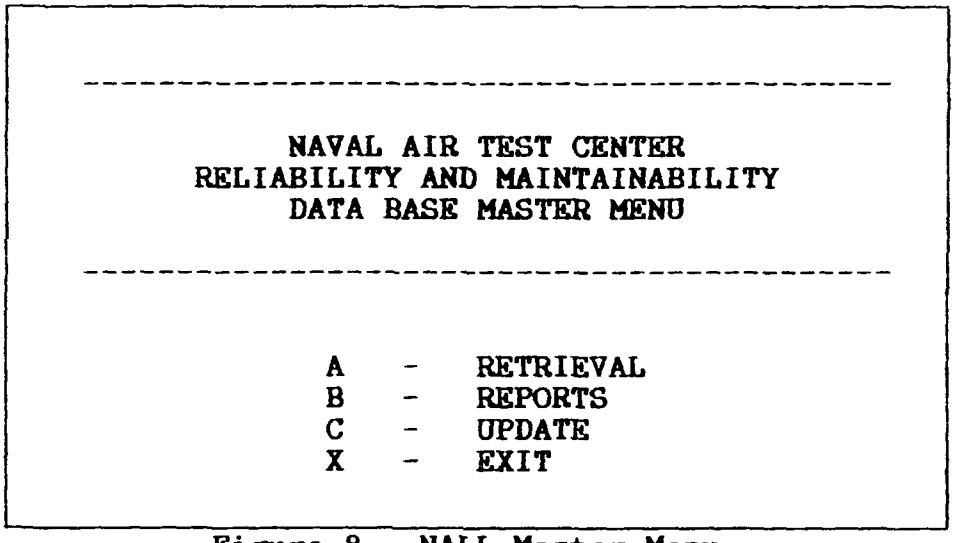


Figure 8. NALL Master Menu
(NALL, 1989)

The RETRIEVAL search method allows a different series of category searches than the REPORTS section and does not generate an index of the lessons found during the search. The REPORTS search method automatically produces an index of the lessons-learned found during the search. It also allows retrieval by NATC number and can build a series of abstract

reports containing only the lesson learned and appropriate action, or the topic and work unit codes (Dove, 1989). The REPORTS and RETRIEVAL menus are shown in Figures 9 and 10, respectively.

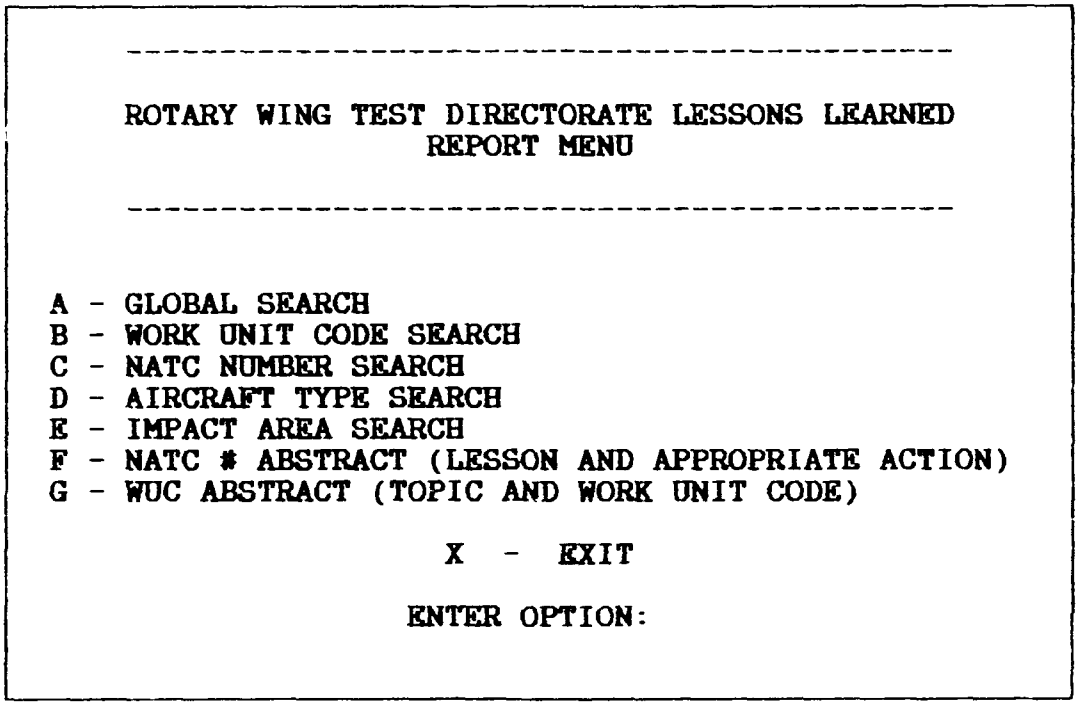


Figure 9. NALL Report Menu
(NALL, 1989)

The REPORTS search method allows either category searches or global searches. The RETRIEVAL search method allows either global searches or searches based on work unit codes, NATC numbers, aircraft type or impact area. Global searches scan the entire lesson for the chosen keyword(s). Category searches scan only the user specified section of the lesson (appropriate action, problem, etc.) for the chosen keyword(s). Both global and category searches bring

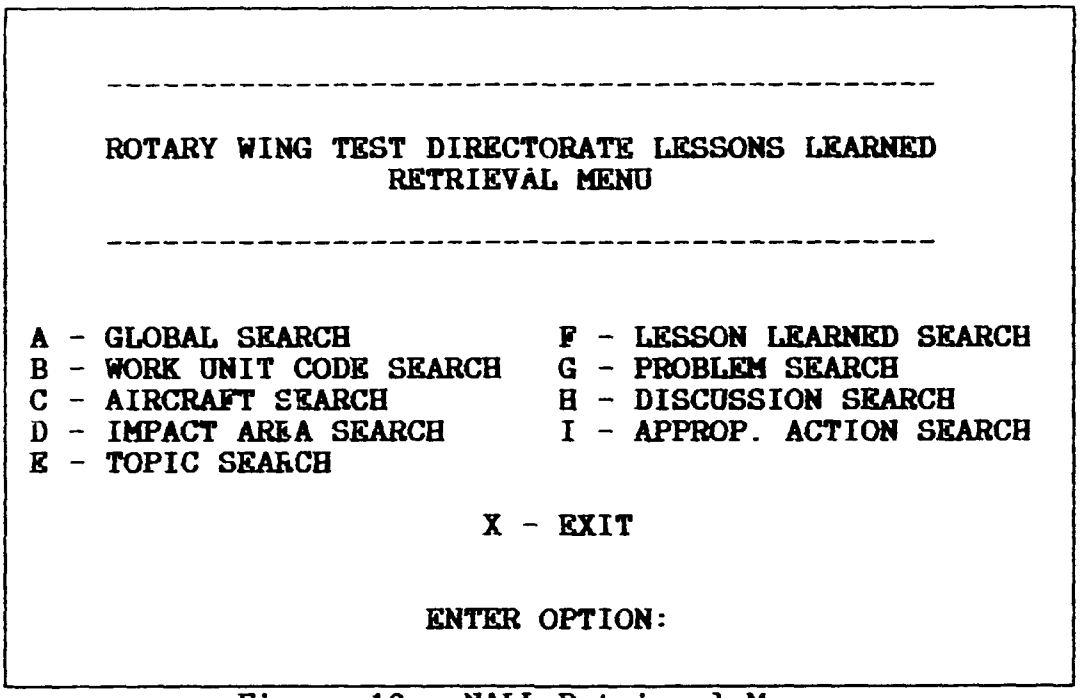


Figure 10. NALL Retrieval Menu
(NALL, 1989)

the NATC number, access number, and topic of the lesson to the screen for viewing or printing. Alternatively, an index can be generated for display consisting of the NATC number and the topic and page number of the lesson. After review of the index, the lessons are displayed.

Keyword searches are "and" type searches which require all of the key words to be found in the lesson before the lesson will be retrieved. Before beginning keyword searches, the system prompts the user, "DO YOU WANT A COUNT?". A "Yes" response advises the user how many lessons will be retrieved. Depending on the count and the user's needs, the search can be made narrower or broader by the keywords specified. The more keywords, the narrower the search. All other searches are "or" type searches where

only one of the numbers selected must match for a lesson retrieval to occur (NALL User's Manual, 1989: 14-20).

Data Sorting and Retrieval. Once the user has selected either the REPORTS or RETRIEVAL search methods and pressed the menu option for the specific search desired, the NALL presents a SORT OPTIONS menu to allow the user to sort the lessons on either NATC number, work unit code or aircraft type. After the search has been initiated from the SORT OPTIONS menu, the NALL provides an "X SYSTEM" prompt at the bottom of the screen to indicate that the retrieval and/or report is being generated (NALL User's Manual, 1989: 21-59).

If the retrieval was generated through the REPORTS search method, completion of the search is indicated by the appearance of an index on the screen. The user may then scroll through the index to review which lessons were generated by the search. Immediately following the index are the lessons themselves, sorted according to the method selected from the SORT OPTIONS menu. If the retrieval was generated through the RETRIEVAL search method, completion of the search is indicated by the appearance of a "TOP OF DATA" prompt at the top of the screen. The user may then scroll through the lessons retrieved (NALL User's Manual, 1989: 60-61).

Printing Lessons-Learned. Hard-copies of the lessons retrieved and/or reports generated are easy to obtain from the NALL system. When the user reviews the

lessons retrieved, the system initiates the prompt, "DO YOU WANT THIS PRINTED?" on the screen. If the user enters "Y" (for yes), a new prompt appears offering the user the choice of remote or local printing. Local printing refers to printing at the Naval Aviation Test Center. Selection of "Remote" printing will initiate a small program that transmits the lessons from the Naval Air Test Center Amdahl mainframe to the printer at the remote user's location. A series of prompts such as "TURN PRINTER ON, ALIGN PAPER, PRESS ENTER WHEN READY" leads the user through the necessary steps in printing the lessons. Upon completion of printing, the user is presented a menu offering the choice of returning to the main lessons-learned menu or exiting the system and logging off. Once the user completes the session and logs off, a final prompt showing total estimated session cost, based on computer CPU time, appears on the screen (NALL User's Manual, 1989: 62-65).

The Navy does not bill NALL system users for the CPU time costs associated with system usage. The Navy firmly believes "all system usage costs are saved many times over by the prevention of costly errors and the improved reliability and maintainability" achieved through the application of lessons-learned (Grimsley, 1989).

System Benefits. The implementation and use of the NALL system has saved the Navy millions of dollars and prevented an indeterminable amount of lost time due to accidents and injuries (Gardiner and Grimsley, 1989).

Several examples demonstrating the usefulness of the NALL were provided by Grimsley. Two of those examples will be examined here.

The first example applied to the fuel management panels within the cockpit of the F-14 aircraft Navy-wide. The existing fuel management panels were under contract to be replaced with liquid crystal display (LCD) type panels which consume less power. The new LCD panels met all required specifications and the conversion seemed imminent. However, based on a lesson learned in the NALL concerning LCD displays, a new LCD fuel management panel was installed in an F-14 and subjected to lighting similar to operational conditions. The NALL-inspired field test proved the LCD panels would not function in the F-14 as desired and the contract for conversion was cancelled before substantial costs were incurred (Grimsley, 1989).

The second example of a NALL lesson benefitting the Navy concerned human lives. NALL researchers monitoring mishap reports for potential lessons-learned noted a disturbing trend. Aircrew members were suffering helmet loss during 62.5 percent of ejections occurring over 300 knots. This trend coupled with other factors led to the identification of serious flaws in redesigned aircrew helmets. The new helmets had been redesigned with less material in the lower rear portion to increase maneuverability; unfortunately, this change also increased the probability of helmet loss and resultant aircrew injury

during ejections. The older helmets had a loss rate of less than 23 percent. Because of the NALL, the helmet loss problem has been identified and corrected (Grimsley, 1989).

NALL personnel related several other examples of NALL lessons being utilized to reduce costs, increase reliability and maintainability, improve acquisition practices, increase quality and improve safety and effectiveness in various aviation systems (Grimsley, 1989).

NALL Bulletin Board. To further increase the NALL system's user-friendliness and reduce the NALL system's mainframe CPU-time costs, the Navy has recently brought on-line the Naval Aviation Lessons-Learned Remote Bulletin Board System (RBBS) (Blankenship, 1989). As stated in the RBBS welcome message, "The Lessons-Learned Remote Bulletin Board System is for the dissemination of information from the Naval Aviation Lessons-Learned Program" (Grimsley, 1989).

The RBBS was initiated for several reasons. One of the principle motivators of the RBBS was the recognition by the NALL system operators that certain types of lessons were pulled from the NALL main-frame database far more frequently than others. The advantage of a PC-based RBBS containing "hot" lessons-learned reports is reduced cost. The NALL operators realized the "hot" topic lessons-learned reports could be retrieved from the main-frame once (with associated CPU-costs) and loaded onto a personal computer (PC) for repeated access "free" through a bulletin board system.

For all practical purposes, the cost of operating a PC RBBS is nothing (Grimsley, 1989). The CPU costs of the Amdahl main-frame are currently in excess of $1500 per hour. (NALL User's Manual, 1989: 65). Additionally, because the lessons-learned packages loaded onto the RBBS are archived, i.e. compressed electronically, the user's download time is reduced by better than 90 percent, which decreases the user's long distance phone costs (Grimsley, 1989).

The NALL RBBS also offers another avenue for user input of potential lessons into the NALL system. Potential lessons can be uploaded to the RBBS where they will be forwarded to the research staff. Users can also directly communicate with the NALL operators via the message and help options built into the RBBS (Blankenship, 1989).

In addition to cost benefits, the NALL RBBS is even more user-friendly than the NALL system because it is structured similarly to many of the more popular PC bulletin boards in use today. The NALL RBBS is a menu driven bulletin board built using RBBS PC software, version 16.1 (Grimsley, 1989). The RBBS resides on an IBM-XT personal computer in the main office of the NALL system operators. The NALL system operators configured the menus of the RBBS to be as simple and self explanatory as possible (Grimsley, 1989). Although still in its infancy, the NALL RBBS has proven very popular with the NALL users. The opening menu of the NALL RBBS, with the options as shown in Figure 11, provides an indication of the RBBS capabilities.

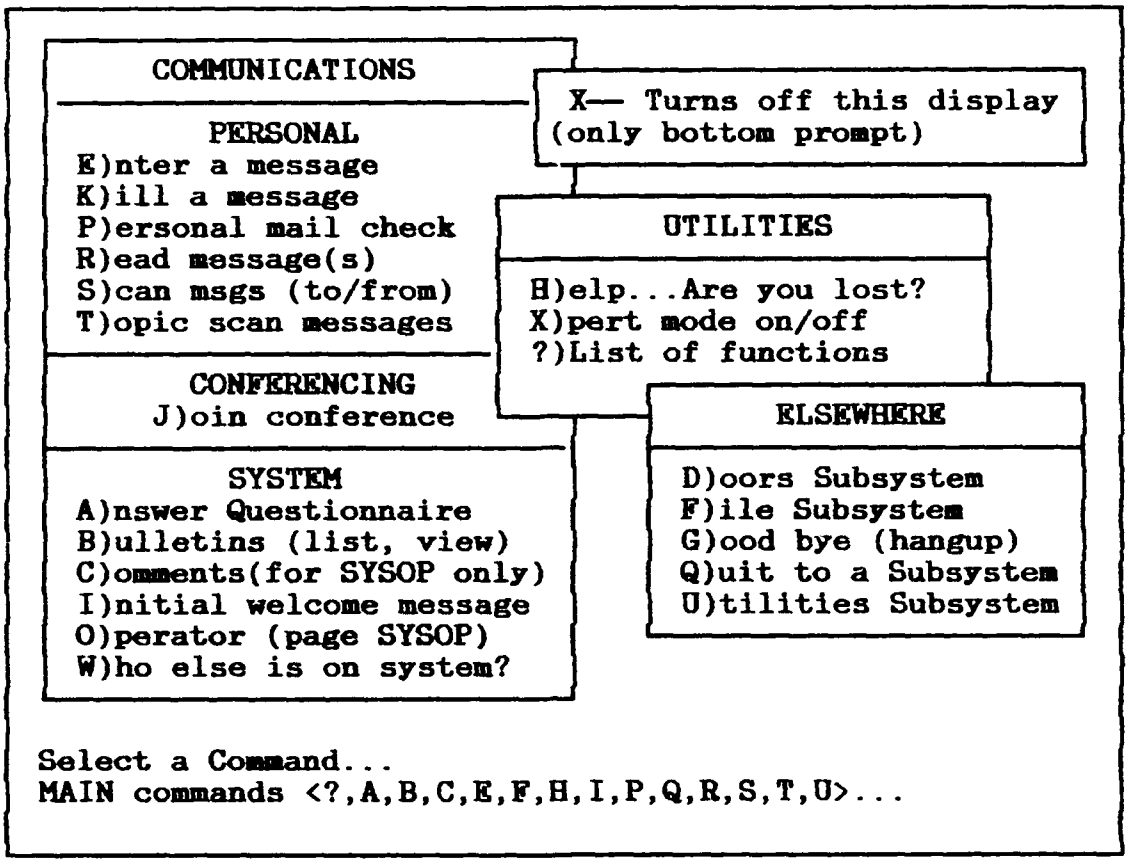


Figure 11. NALL Bulletin Board Main Menu (NALL RBBS, 1989)

Logging onto the NALL RBBS requires only a personal computer, modem and the RBBS phone number. Unlike the NALL, access to the RBBS does not require prior approval from the Naval Air Test Center; however, prior approval must be obtained before uploading and downloading is allowed. New users are limited to reading the bulletins, answering questionnaires and reviewing the RBBS directories (Blankenship, 1989).

Users of the RBBS have access to the "hot" topic lessons discussed previously. Alternately, through the

RBBS, users may leave requests for the system operator (SYSOP) to search the main-frame NALL system for non-"hot" lessons meeting certain criteria. The SYSOP performs the lesson retrieval from the NALL and loads the lessons/reports onto the RBBS system for later downloading by the requesting user (Grimsley, 1989).

Recommendations. The NALL developers provided several in-sights into what makes an on-line lessons-learned system such as the NALL system successful. The recommendations noted follow:

1. DEFINE USERS INTERFACE REQUIREMENTS. This should be done down to the smallest detail, such as how the user would like the individual menus to appear and which keys will perform which functions.

2. DATA REQUIREMENTS. As far as the system programmer is concerned, "data is data". The user must convey to the programmer how the data is used in day-to-day operations. Information such as a) how the data is normally presented or viewed, b) how the data is received or input, c) how the data is manipulated, d) how the data is sorted and e) how the user wants to retrieve the data - must be fully explained to the programmer.

3. USER-FRIENDLINESS. Any system that will be used must be user-friendly. User-friendliness features -- such as extensive built-in help screens, clear menus, self-explanatory individual menu options, etc. -- all increase user-friendliness. Conversely, a means of disabling the

menus and choosing command driven options should also be incorporated so that the experienced user can avoid the menus if desired. The user must always be able to back out of a incorrect entry by hitting an "undo" key (Grimsley, 1989). This prevents the novice from getting stuck at a menu level and not being able to get back out.

4. DOCUMENTATION. Documentation is also critical to user-friendliness. New users of the NALL are provided an extensive, well-written, 112-page User's Manual. The User's Manual provides a step by step explanation of how to log onto the system, access the database, perform lessons-learned searches, generate reports, generate retrievals, print lessons and reports, exit the database and how to reconnect to the system if connection is interrupted. Also provided in the User's Manual are keyboard mapping diagrams, hardware and software configuration directions and explanations on how to alter the configurations to match the user's system. The User's Manual has ten appendices further explaining the NALL. The User's Manual Appendix 1 provides a sample format letter for requesting access to the NALL. Appendices 2 through 4 of the User's Manual list the acceptable impact areas, work unit codes and aircraft type codes. Finally, the User's Manual Appendices 5 through 10 provide program code listings for the various database programs used on the NALL to retrieve lessons, print lessons, etc. The program code listings are included in the User's Manual for reference purposes only.

5. CROSSFEED AND COMMUNICATE. The users, owners and programmers must continually communicate to ensure the expectations and efforts of each individual are known in advance. Bi-weekly meetings during the development stage are extremely beneficial in preventing wasted effort on the part of the programmers and unmet expectations on the part of the user (Dove and Grimsley, 1989).

6. ADVERTISE. Once a lessons-learned system is on-line, it is critical that its potential users know of its existence. Lessons-learned are not static entities, but continually evolve and change with technology, personnel, and management changes. The NALL team has visited hundreds of Naval Stations, contractor facilities and other sites, always seeking new users and new potential lessons (Grimsley, 1989).

NALL Summary. The Naval Aviation Lessons-Learned system is one of the largest and most user-friendly lessons-learned system found in the DOD. Over 90 percent of the feedback received from the NALL's users indicates it is "extremely helpful, well thought out and easy to use" (Grimsley, 1989). The development of the NALL system followed a "quasi-prototype, quasi-systems analysis" methodology (Dove, 1989). As a result of the NALL's success, both the Army and Air Force have visited the Naval Aviation Lessons-Learned center to gain insight into how to configure their respective service's lessons-learned programs. Similarly, several defense contractors have

initiated lessons-learned systems modelled after the NALL or had the NALL program installed at their sites by the NALL team (Grimsley, 1989).

Air Force Lessons-Learned On-Line Access. The U.S. Air Force has also recognized that "lessons-learned can and do impact system acquisition" (Kerr, 1989). Consequently, the Acquisition Logistics Division (ALD) at Wright Patterson AFB, Ohio established the Air Force Lessons-Learned Databank (AFLL) in 1977, and automated the AFLL in 1978. AFLL is "by far, the largest and most mature of the various 'Lessons-Learned' (corporate memory) data banks now in operation" (On-Line Access, undated: 6). The principle goal of the AFLL is to,

> Provide feedback for improving all aspects of Air Force Operations. Application of lessons-learned is the bottom line. If they are to be applied, they must be communicated to the decision makers in current programs. (On-Line Access, undated: 6)

History. The Acquisition Logistics Division was originally formed to help bridge the gap between the acquisition and logistics communities to improve the reliability and supportability of new weapons systems coming into the Air Force inventory. To help meet this goal, ALD initiated the Air Force Lessons-Learned Program (Keith, 1989). The AFLL system is included in the tri-service Joint Agreement on the Joint Logistics Commander's Lessons-Learned discussed in the Naval Aviation Lessons-Learned section. As defined by ALD, a lesson learned is a "recorded experience,

that can be of value in the conduct of future programs" (On-Line Access, undated: 6).

The initial AFLL lessons-learned were collected by lessons-learned teams. These teams conducted field trips to a variety of sources including private industry, Air Logistics Centers, AF Safety Center, MAJCOMS, Air Force Systems Command Product Divisions, conferences/meetings and DOD agencies. The AFLL system has 377 on-line access users, however many "users" are in fact organizations which may have 30 or 40 personnel sharing one user-id and password (Kerr, 1989).

System Configuration. The AFLL database is hosted on Aeronautical Systems Divisions' Information Central Division System 1 (VAX 11/780), minicomputer located at Wright-Patterson AFB, OH (On-Line Access, undated: 6). Batelle's Automatic Searching and Indexing System (BASIS) controls the actual lessons-learned data manipulation (Keith, 1989). The AFLL can be accessed through any terminal directly tied to the VAX mainframe. Alternatively the AFLL is accessible to remote personal computer users possessing a user-id and password provided by the ALD upon request. Remote users must have a personal computer, a modem and a communications package capable of emulating a VT100 terminal. Other terminal emulators will work, but a VT100 emulator works best. Finally, the AFLL is accessible through the Defense Data Network (DDN) (On-Line Access,

undated: 12). The AFLL is available for access 24 hours per day, seven days per week (Keith, 1989).

AFLL Database Configuration. The AFLL database currently contains over 2000 technical and management lessons-learned (Purvis, 1989). As outlined in the AFLL On-Line Access User's Guide, each lesson contains the six different fields shown below:

1. CALL NUMBER: An office assigned, sequential number, by which each unique lesson can be identified and retrieved.

2. TOPIC: Brief but representative description of the content of the lesson.

3. LESSON LEARNED: One or two concise sentences, showing a cause and effect relationship, and stating the single most important finding.

6. PROBLEM: Normally no longer than one or two brief sentences, this field will say "none" for positive lessons-learned.

7. DISCUSSION: One to three paragraphs giving as complete an account of the situation as possible.

8. APPROPRIATE ACTION: This is the most important part of a lesson learned. It will detail who should accomplish, what task, when in the acquisition cycle to apply the knowledge previously gained in that situation. (On-Line Access, undated: 9).

The format of the AFLL lessons-learned is very similar to the format of the Navy's NALL lessons-learned. The Air Force and Navy lessons-learned offices frequently share information and ideas to improve both systems (Grimsley, 1989; Kerr, 1989). A transcription of a sample lesson retrieved from the AFLL is shown in Figure 12.

Data Input. Potential lessons-learned for the AFLL are obtained from a variety of sources including successful

CALL NUMBER: 0728

TOPIC: ENGINE STARTING

LESSON LEARNED: The use of gear tooth coupler pawls for dynamic engagement in the engine starting cycle should be avoided unless torsion surges can be accommodated through a torsion shaft fluid coupling, or flat disk clutch.

PROBLEM: Excessive maintenance manhours and high level of force degradation have resulted from the engine starting engagement system design using pawls.

DISCUSSION: The high performance fighter aircraft central gearbox (CGB) engages an airframe mounted accessory gear box through a gear-type pawl to transmit engine starting torque from the jet fuel starter to the engine. The shock loading of the pawls during ratcheting/grinding engagement destroys the pawls and creates a large shear stress on the coupling stubs.

The high performance fighter aircraft force degradation contribution listing ranked the CGB (WUC 24ANO) as eighth and the coupling stub (WUC 24ANH) as twenty-eighth. Zero RPM engagement parameters are not compatible with operational reality of consecutive start attempts without attaining zero RPM between attempts.

APPROPRIATE ACTION: Future engine starting subsystems should be designed to avoid dynamic pawl/gear engagement and minimize shock loading of the system with shear stresses. The use of air turbine motors, electric motors, fluid couplings or slip disk clutching as alternatives to hard engagement should be considered.

Figure 12. Sample AFLL Lesson
(AFLL, 1989)

or unsuccessful acquisition program experiences, personal experiences, test reports, inspection deficiencies, maintenance data, engineering data and contractors. Also, all users of the AFLL are encouraged to submit potential lessons to ALD by the AFLL opening message of the AFLL:

> In order to stay abreast of changing technology affecting weapon system development and maintain a dynamic data base the Air Force lessons-learned program relies on feedback from each organization (DOD or contractor) that designs, acquires, operates, or supports an Air Force system. To achieve this goal we welcome potential lessons-learned submittals from anywhere and anyone. One of the options on the following main menu screen has been provided for you to pass potential lessons directly to the Data Bank staff for validation. (AFLL, 1989)

Potential lessons-learned are submitted on an Air Force Form 1251 to ALD Directorate of Lessons-Learned and Systems Support (ALD/LSL) for research and validation. The potential lesson learned is then reviewed for validity by one of several "functional experts" in ALD. A potential lesson is considered valid if it is "technically accurate and not contrary to established regulations" (Keith, 1989). Unlike the Navy Lessons-Learned database which has an in-house staff of researchers whose primary duty is lessons-learned research and validation, the AFLL validates potential lessons with the help of functional experts operating in an "additional duty" capacity (Keith, 1989). ALD/LSL maintains of a file of over 2,000 "no lessons-learned" obtained from lessons that have been overcome by events, or submitt.ls that could not be validated (Kerr, 1989).

Upon completion of the validation, the researcher conducts a format review of the lesson for compliance with the "cause and effect" relationship and "who, what, when" format desired in all AFLL lessons (Keith, 1989). The cause

and effect relationship explains "if an action is/is not accomplished what event will/will not occur" and the who, what, when explains "in detail who should accomplish what task, when in the acquisition cycle to apply the lesson" (On-Line Access, undated: 8). After the format review and validation of the lesson by the functional expert, the approved lesson is signed off by the Director, ALD/LSL and entered into the AFLL database (Purvis, 1989).

The Air Force follows the same policy as the Navy regarding sanitizing of lessons-learned, for the same reasons, i.e. all lessons-learned will be sanitized such that neither the lesson nor the backup documentation attached contains any reference to the person, unit, organization or firm associated with the lesson (Keith, 1989).

Data Retrieval. Like the Naval Aviation Lessons-Learned system, the AFLL is also menu-driven allowing the user to select which activity is desired from a preset "menu" of options. Each menu is self-explanatory and the options available are clearly shown. The opening menu of the AFLL system allows the user to select from a variety of options including searching for lessons, submitting potential lessons, and others as shown in Figure 13. Rather than pressing a number associated with a particular menu option, the AFLL menus are configured to allow option selection by pressing the first letter associated with the menu option desired (AFLL, 1989).

U.S.A.F. Lessons-Learned DATA BANK **MAIN** MENU

Line number 1 with 2131 lessons.

Please select by LETTER from the options listed below.

S. (S)earch/Retrieve specific lessons.

P. submit (P)otential lessons to the data bank.

C. leave (C)omments/Suggestions for the data bank staff.

U. go to (U)tilities menu.

L. change menu drive (L)evel (amount of assistance provided).

Q. (Q)uit the data base.

(S)earch,(P)otential,(C)omment,(U)til.,(L)evel,(Q)uit?=

Figure 13. AFLL Main Menu (AFLL, 1989)

Lessons input into the AFLL are indexed into categories with the use of logistics elements and management elements.

> Management Lessons address program decisions and actions in such areas as program control, budget/financial control, contracting techniques, support planning, configuration management, maintenance concepts and data management.
>
> Technical Lessons relate to systems, equipment and components, including hardware, software, support equipment, or the design factors that influence the performance of the system or equipment. (Keith, 1988: atch 2)

This allows users to conduct narrower keyword searches in a particular area, without retrieving lessons containing the keyword but no applicable data. Conversely, all lessons within an area can be retrieved without keyword searches.

The management and logistics elements of the AFLL are shown here:

LOGISTICS ELEMENT AREAS	MANAGEMENT ELEMENT AREAS
1 COMPUTER RESOURCES (SUPPORT)	30 CONFIGURATION MANAGEMENT
2 ENERGY MANAGEMENT	31 CONTRACT ADMINISTRATION
3 ENGINEERING DATA (TECH. DATA)	32 CONTRACTING
4 FACILITIES	33 DATA MANAGEMENT
5 FUNDING (LOGISTICS SUPPORT)	34 ENGINEERING
6 LOGISTICS MGT. INFO. SUPPORT	35 FOREIGN MILITARY SALES
7 MAINTAINABILITY	36 HUMAN FACTORS ENG.
8 MAINTENANCE CONCEPT (PLANNING)	37 LIFE CYCLE COST
9 MODIFICATION PLANNING	38 MANUFACTURING
10 MANPOWER REQUIREMENTS	39 OPERATIONAL REQUIREMENTS
11 RELIABILITY	40 PROGRAM CONTROL
12 RELIABILITY & MAINTAINABILITY	41 QUALITY ASSURANCE
13 SAFETY	42 SOURCE SELECTION
14 SUPPLY SUPPORT	43 PROG. MGT. TRANSFER
15 SUPPORT EQUIPMENT	44 LOG. SUPPORT ANALYSIS
16 SURVIVABILITY	45 PROGRAM MANAGEMENT
17 TECHNICAL ORDERS (TECH. DATA)	46 ENVIRONMENTAL MANAGEMENT
18 TEST AND EVALUATION	47 WARRANTIES
19 TRANS. PACKAGING & HANDLING	
20 TRAINING AND TRAINING SUPPORT	
21 ARTIFICIAL INTELLIGENCE	

(AFLL, 1989).

Data Sorting and Retrieval. If the user selects the "(S)earch/Retrieve specific lessons" menu option, a submenu is presented offering the user a selection of various search and retrieval methods. The (S)earch/Retrieve submenu is shown in Figure 14. The flexibility of the AFLL Search/Retrieve options allows the user to retrieve lessons many different ways. Wordsearch retrievals, either of the entire file or only a particular log or management element, search based on an "and" type search, which requires all of the key words to be found in the lesson(s) before the lesson(s) will be retrieved While the AFLL system supports

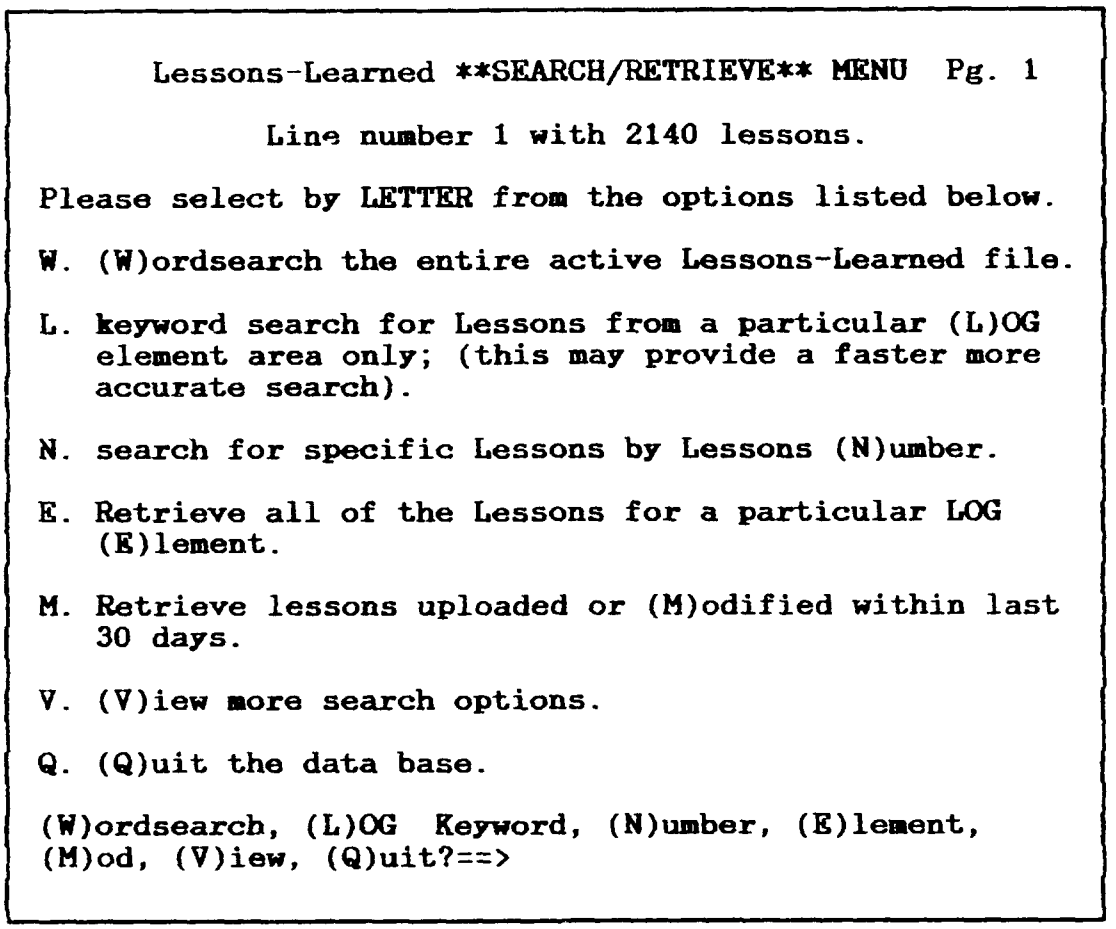


Figure 14. AFLL Search/Retrieve Menu (AFLL, 1989)

multiple wordsearching, (up to 6 words or 58 characters) it does not accomplish "phrase" searching, i.e. the words in the search string will be contained somewhere in the lessons retrieved, but may not be in the exact sequence of the search string (On-Line Access, undated: 19). The further options of the sort and display/print menus are shown in Figures 15 and 16. Upon search completion, the AFLL advises the user how many lessons have been found and prompts the user with several options including listing the lesson

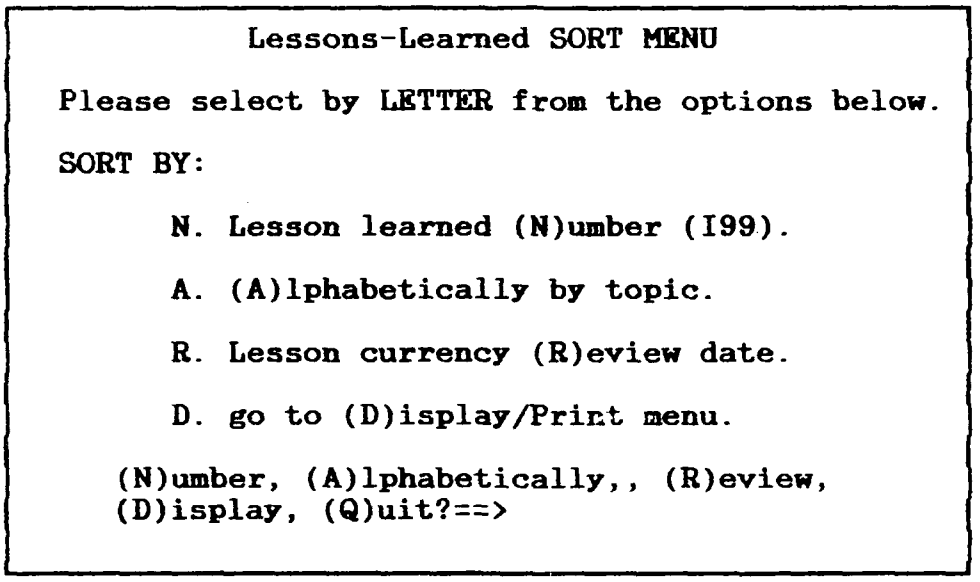


Figure 15. AFLL Sort Menu (AFLL, 1989)

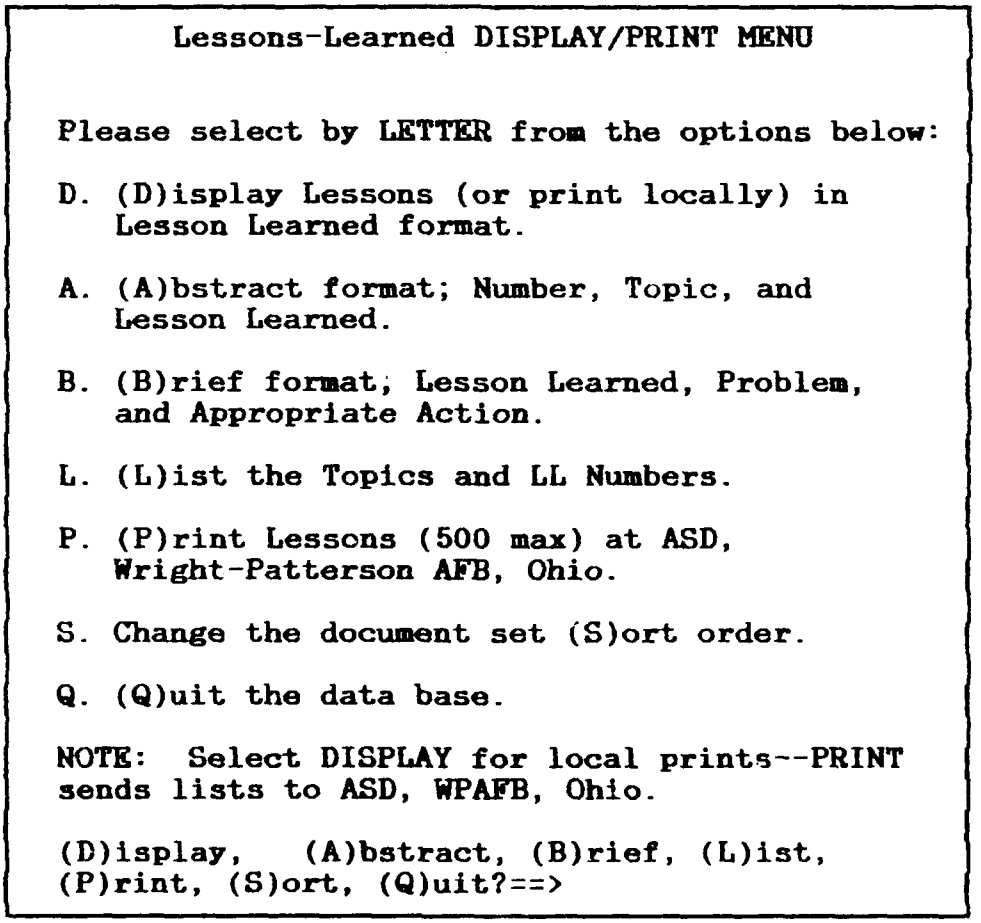


Figure 16. AFLL Display/Print Menu (AFLL, 1989)

topics and numbers, conducting another wordsearch, quitting the database or entering the sort or display/print menus.

Printing Lessons-Learned. Hard-copies of the lessons retrieved from the AFLL system can be printed either at the user's remote location (through the (D)isplay option of the Print/display menu) or at the host computer printer at Wright Patterson. There is normally a one day turnaround on lesson printing at the host computer (On-Line Access, undated: 19). Alternatively, users may make mail or phone requests to ALD/LSL for hardcopy lessons-learned information, abstracts (brief synopsis of all lessons), bulletins (lessons on specific topics such as composites, engines, quality assurance, etc.) or lesson packages tailored to the user's needs (On-Line Access, undated: 6).

Four distinct lesson formats can be obtained from the AFLL including 1) Lesson Learned Format which displays all information; 2) Abstract Format which displays only the call number, topic, and lesson learned statement; 3) Brief Format which displays all information except the discussion; and finally, 4) Topics and Numbers Format which displays only the call numbers and lesson topics in tabular format (On-Line Access, undated: 8).

The Air Force does not bill AFLL system users for the CPU time costs associated with system usage for the same reasons the Navy does not bill NALL system users - system usage costs are saved by the prevention of costly mistakes

and improved reliability and maintainability achieved through the application of lessons-learned (Keith, 1989).

System Benefits. The implementation and use of the AFLL system has yielded substantial benefits to the Air Force. However, quantification of these benefits is extremely difficult. One indication of the success of the AFLL is the current interest of ALD/LSL in expanding the AFLL's capabilities to include, among others - graphics, proximity searching, spell checking and cut and paste functions. Another indication of AFLL success is system usage - approximately 600 new potential lessons are received yearly by ALD/LSL for research and validation (Kerr, 1989).

Recommendations. The AFLL developers provided several in-sights into what makes on-line lessons-learned systems successful. The recommendations noted were similar to the NALL developer's recommendations and also included:

1) ADVERTISE. Let the people know who you are. ALD/LSL advertises through the use of pamphlets, base newspaper articles and briefings to other organizations. ALD/LSL has promoted lessons-learned at the Air Force Institute of Technology and the Senior NCO Academy. In essence, if the user isn't aware of the lessons-learned program, the program can not be successful (Kerr, 1989).

2) VALIDATE. Lesson validation is critical. If users conduct searches only to discover lessons that are technically incorrect, counter to established regulations, outdated or otherwise inappropriate they will very soon quit

using the lessons-learned system. Validation must be a continual process, where lessons are reviewed frequently and updated as necessary (Kerr, 1989).

3) KEEP IT SIMPLE. Lessons-Learned systems must be simple to use. The AFLL operators consider this an endless process. Users are encouraged to advise ALD/LSL of any problems encountered or suggestions that might improve the system's simplicity. A recent example of this, related by Kerr, involved users having difficulty preventing the lessons from scrolling across the screen too fast. Although only certain users were experiencing this problem, ALD/LSL modified the AFLL to include page breaks every 20 lines in the lessons, thereby solving the problem (Kerr, 1989).

AFLL Summary. The Air Force Lessons-Learned system is the largest and oldest lessons-learned system found in the DOD (Keith, 1989). The lessons-learned in the AFLL system are weapon systems acquisition oriented and normally written in a concise format, one typed page or less, for user convenience and readability (Purvis, 1989). The development of the AFLL system did not entail a full systems analysis, but instead followed a quasi-prototype, quasi-systems analysis methodology (Kerr, 1989). The AFLL allows users to search for, retrieve and print lessons in many ways. As a result of the AFLL's success, efforts are now underway to expand the capabilities of the AFLL.

V. Findings Related to WANG MIS Development

Introduction

Chapter V provides the answer to the one remaining research question that has not yet been addressed. Namely, "From the user's perspective, how should the proposed lessons-learned MIS be structured?". As noted in the methodology, this question was answered through the use of interviews. Interview questions are shown in Appendix A. Answers to the interview questions are presented below.

The User's Perspective

Profile of the User. The first portion of the interview established a profile of the users selected for interviewing. This profile is provided as a baseline to understanding who the users are, in terms of experience and background, both in construction management and computers.

Experience. The users interviewed were both military and civilian in the grades of captain, major, GS-13 and GM-14. The users' experience in construction management ranged from a low of 4 years to a high of 16 years, with an average experience of 10 years. All of the interviewees have worked a broad range of construction efforts, from small, low-dollar, base-level construction/repair to large, AFRCE- or MAJCOM-level, multi-million dollar new construction. Within the context of construction management, the interviewees have all functioned to some

degree as inspector, designer, technical advisor, design manager, construction manager, and project manager. All of those interviewed related that experience is crucial to successful construction management.

In terms of computer experience, all of those interviewed appeared to have similar ability and understanding. All of the interviewees are familiar with computers, and use computers in their current jobs. The interviewees typically use computers for project management, scheduling, word processing, database manipulation and spreadsheet calculations. Although most familiar with MS-DOS or MacIntosh personal computers, the interviewees all expressed some familiarity with the WANG/WIMS computer system. All but one of the interviewees has written computer programs either in Fortran, Basic or a higher-level computer language, although none proclaimed proficiency in this area. One interviewee found the WANG computer system somewhat user-friendly, while the others considered the WANG less than user-friendly. Only two interviewees had heard of the concept of on-line lessons-learned systems.

General System Parameters. When completely unconstrained, the interviewees proposed several interesting ideas on what the ideal on-line lessons-learned system would be like. Many envisioned systems that would be interactive on both an audio and visual basis.

The Ideal System. The ideal system would allow users to store lessons in much the same way as pocket-size

tape recorders work, by simply turning on a small recorder and explaining the lesson. The recording devices could be taken to the construction site and used whenever and wherever a lesson was learned. In addition to the voice lessons-learned description, a visual picture of the actual problem and solution could be captured. Retrieval of the lessons from the ideal system would also be voice activated. The lessons-learned seeker could audibly request all lessons that meet certain criteria. Upon completion of the data search, the system would audibly prompt the user with a brief synopsis of the lessons found. If a lesson synopsis appeared applicable, the user could then audibly request additional information with full video complements. Other variations on this theme were also postulated by the interviewees.

Realistic Systems. All of the interviewees acknowledged that the proposed ideal system could not be practically expected in the near future. In lieu of the ideal system, the interviewees provided several ideas of what a capable lessons-learned system would be, within the financial, technical and political reach of Civil Engineering.

The users interviewed provided three different concepts for the proposed lessons-learned system. One concept envisioned a system containing lessons stored in much the same way as data in an electronic encyclopedia. Lessons would be stored according to the type of work -- structural,

mechanical, electrical, etc. Users would then have a master index of all major work areas and could seek out lessons by retrieving only the desired area of interest.

For example, if the user knew the contractor was about to begin the interior electrical work within a facility, the user could select ELECTRICAL from the various types of work. This is conceptually similar to pulling one volume from a set of encyclopedias. Next, the user could select what subarea within the major area of ELECTRICAL work was appropriate, from such options as INTERIOR, EXTERIOR, etc. This is similar to turning to a specific chapter within the encyclopedia volume selected. Successively, the user then proceeds through his selection down to the actual lessons. The actual lessons may be several menus down, for example - lessons on electrical panelboard work, in main distribution systems, within the interior of a facility could be four menus down from the top menu.

The encyclopedia style system would be menu-driven, and the user would not have to enter any information, merely select from a choice of options. Each menu selection would yield a submenu of subareas within the menu one level up. An example of menus and submenus of this type of system is shown in Figure 17.

A second proposed concept for the lessons-learned system's structure is very similar to that used by the NALL and AFLL systems. Under this concept, the user performs searches of the entire database with retrieval based on

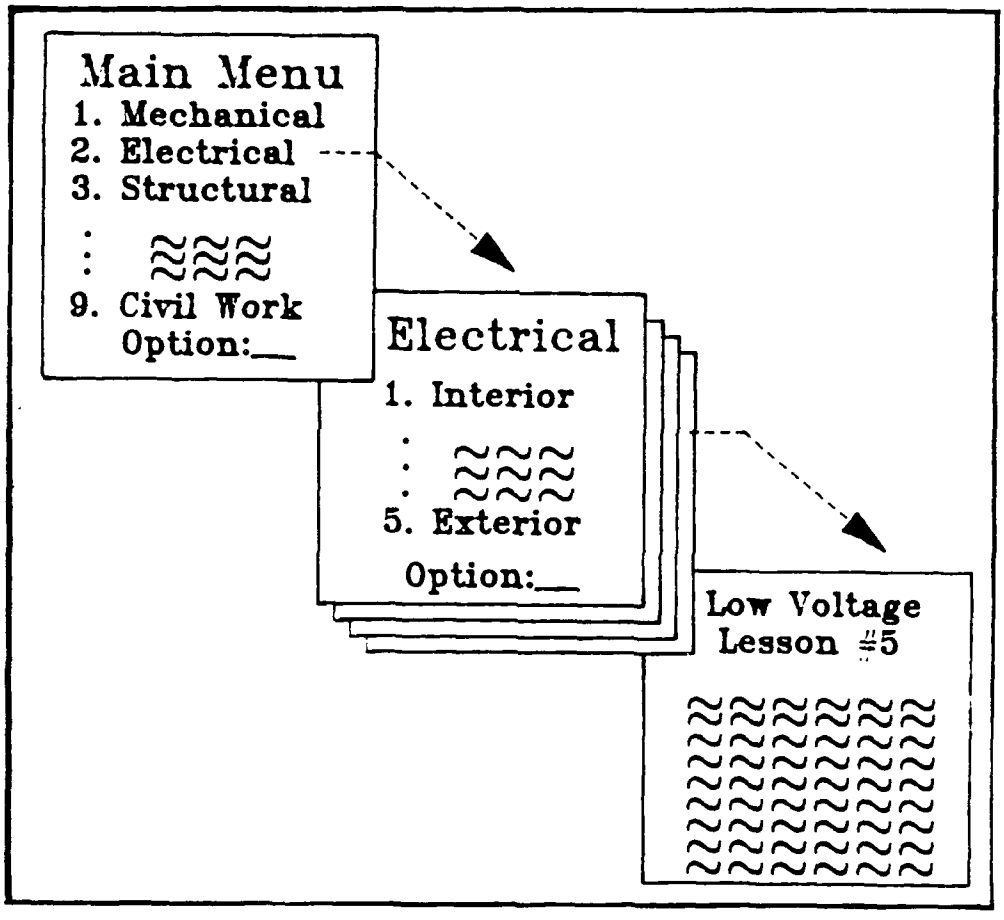


Figure 17. Encyclopedic Style System Menus

criteria specified by the user through a series of menu selections. This search style system would also be menu-driven. The master menu of this style system would allow the user to select from one of three options: SEARCH/RETRIEVE LESSONS, INPUT LESSONS and PRINT/SORT LESSONS. These three options will be explained in the Lessons-Learned Input/Retrieval section of this chapter. The proposed master menu would be similar to Figure 18. All of the menus shown in this chapter are conceptual only.

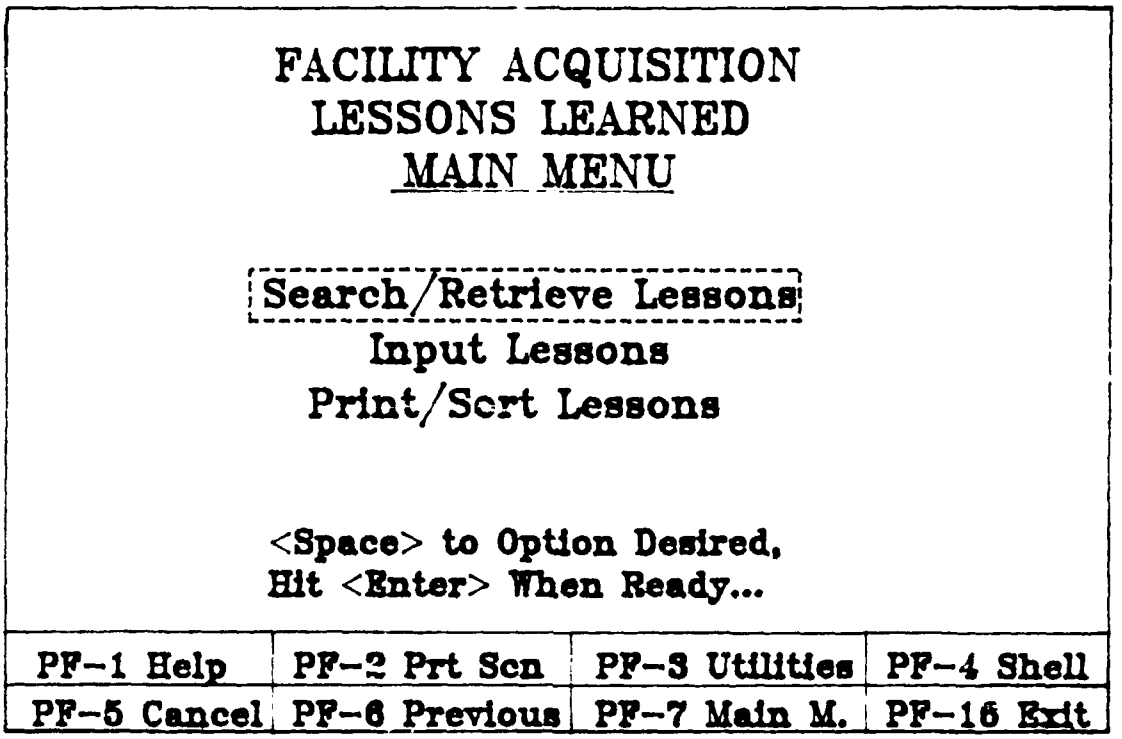


Figure 18. Proposed Master Menu

The third proposed concept was a combination of the first two. Under the third concept, the initial menu would offer the user two methods of system usage -- encyclopedia style, or criteria specified search and retrieval style. The interviewees noted that both methods of system usage could be helpful depending on the type of lesson sought. On those instances where the area is clearly defined within one specific work discipline -- the encyclopedia style would probably be the fastest. For multi-discipline area work efforts, the criteria specification method would work best.

System Characteristics and Functions. Regardless which of the three concepts outlined above is operative, several general systems parameters are equally important.

For example, the lessons-learned system should be on the WANG computer system. The WANG is the system used by Civil Engineering, and building a lessons-learned on any other system would increase costs (for new equipment) and increase training requirements time.

Although the interviewees acknowledged the need to keep the proposed system WANG-based, at the same time all expressed interest in improving on WANG conventions where possible. For example, rather than use programmed function (PF) keys to select menu options, the lessons-learned system should allow menu item selection by either lightbar, number or first letter of the item description. Most interviewees considered selection by lightbars preferable to PF-key, number or letter selection. A lightbar is a means of highlighting a menu option such that the active option is shown on the screen in a different color or reverse video. The lightbar is depicted in Figure 18 (on the previous page) as a dotted rectangle around the active option.

PF-keys could be reserved for functions that are universal across all menu levels, on every screen - such as Help, Print Screen, Utilities, Shell to System, Previous Menu, Cancel, Main Menu and Exit. The PF-key options are shown at the bottom of Figure 18 on the previous page. This prevents unnecessary confusion created when the same PF-keys perform different functions at different menu levels.

The Help function should provide drop down panels of text explaining each option on the screen in a concise

format. Extended help text on each option should also be available, but only appear when requested.

The Print Screen function should allow the user to send whatever is showing on the screen at the instant the Print Screen key is pressed to either a file or printer. Pressing the Print Screen PF-key should prompt the user with, "Send Screen to (F)ile or (P)rinter?" Once the user selects "F" or "P", the Print Screen function should determine which output device to send the screen to from the defaults set by the Utilities function. If (F)ile is selected, the user should be prompted with, "Filename?" and allowed to enter a filename where the screen should be saved. Lastly, the user should be allowed the option of appending the information to an existing file.

The Utilities function is envisioned as a means of allowing the user to change several system defaults such as terminal configurations, input/output devices (mouse, keyboard, printer, monitor, etc.) file transfer rates, help levels, menu levels (expert/novice), etc. The Utilities function should allow the defaults to be changed either temporarily (for the current session only) or saved and used as the defaults the next time that user enters the system. The Utilities function should also allow the user to print the full help text document.

The Shell to System function should provide shell capability to keep the lessons-learned system running, i.e. searching or printing lessons, yet allow the user to enter

and temporarily run another application on the computer system. One example of this function provided by the interviewees was if the user was performing a lessons-learned search or print session and needed to run another application such as Project Design and Construction (PDC), the system should allow the search to continue in the background (invisible to the user) while the PDC application was running in the foreground (visible to the user).

The Previous Menu function should allow the user to back out of the menu layers one at a time. The Cancel function should "undo" the last keystroke and return the user to the condition prior to the keystroke. The Main Menu function should go directly to the Main Menu regardless which menu level is currently showing on the screen.

Finally, the Exit function should shut down the lessons-learned system, close all files, etc. The Exit function should prompt the user with "Exit Lessons-Learned? Y/N " for confirmation that the exit is, in fact, desired and not the result of a missed keystroke.

Access to the lessons-learned system should be on a full and restricted basis. Full access users should be allowed to add lessons, retrieve/print lessons, and perform system configuration changes on all areas and lessons. Base, MAJCOM, AFRCE and Air Staff engineers involved in Air Force Construction should be considered full access users. Restricted use should be available to those organizations with indirect involvement in the Air Force construction

process such as contractors, Army COE, NAVFAC, and contracting personnel. Restricted users should only be allowed to access information that has been sanitized.

Lesson Structure. In discussing the structure of the actual lessons-learned, the interviewees were remarkably consistent in their opinions and ideas. Regardless whether the encyclopedia style system or criteria search and retrieval system (or combination of the two) is selected, the length, content and format of the lessons-learned as described by the users is very similar to that used by the AFLL and NALL.

Length. While there should not be a limit on the length of a lesson learned, it is expected a typical construction management lesson learned will be one to two typed pages, single spaced.

Content. Lessons-learned should contain at least the ten sections addressed below:

1. LESSON NUMBER: Internal tracking number unique to each lesson learned, assigned by AFESC or the system.

2. IMPACT AREAS: A listing of up to six major areas that the lesson affects. Examples: safety, engineering, contracting, human factors, health, training, environment, reliability, maintainability, etc. The initial listing of impact areas will be generated by AFESC after a sufficient collection of lessons has been obtained.

3. TOPIC: Title/subject of the lesson learned, brief but representative of the content of the lesson.

4. LESSON LEARNED: The actual lesson learned, its cause and its effect.

5. PROBLEM: Descriptive statement of what went wrong. If the lesson is positive, this area says "NONE".

6. DISCUSSION: In-depth discussion of lesson specifics such as who, what, when and where. This portion

of the lesson is the unsanitized portion -- used only by full access users who need to locate the personnel involved.

7. APPROPRIATE ACTION: Recommendation(s) on possible ways to avoid the problem.

8. FACILITY CODE (FC): Code used to identify the specific type of facility that either generated the lesson or is affected by the lesson. Examples of facility types include administrative, dormitories, military family housing, maintenance, etc.

9. WORK TYPE: Used to identify what type of work generated or is affected by the lesson. Examples include mechanical, electrical, civil, structural, communications, etc.

10. LESSON TYPE: Three choices -- management, technical or both. Used to help reduce volume of lessons searched according to user's needs.

All of the interviewees related that the final selection of lesson content may need to be adjusted after an initial trial period. It is anticipated most users will find or suggest additional content areas and the system should be flexible enough to adapt as required.

Format. The specific format of a lesson learned was not considered critical by the interviewees. The one important aspect of format that must not be overlooked however, is consistency. All of the lessons input into the system, whether submitted by different commands, bases or levels of management, must be consistent. If the user has to waste time from lesson to lesson adjusting to new formats with similar information in different areas, the user is likely to become dissatisfied with the system. The interviewees agreed any format similar to that of the NALL or AFLL lessons would be sufficient for the lessons.

Search/Retrieval, Input, Print/Sort. The most important aspects of the proposed lessons-learned system are lesson search/retrieval, input and print/sort. Unless these functions are easy to accomplish, most users will avoid using the system. All of the interviewees expressed little concern regarding how the data was physically stored within the computer system. Instead, the procedure the users must follow to search/retrieve, input, and print/sort the lessons-learned data was considered very important.

Search/Retrieve. The SEARCH/RETRIEVE menu option should allow the user to perform searches of the lessons-learned database based on user specified keywords or full text phrases, facility code, work type, lesson type or impact areas is necessary. A SEARCH/RETRIEVE menu, similar to that shown in Figure 19, should appear on the screen when the user selects the SEARCH/RETRIEVE option from the main menu.

The user should be allowed to tag the type of searches desired and then be presented additional menus where the specifics of each type of search can be entered. Sample menus for keyword, phrase and facility code searches are shown in Figures 20, 21 and 22 respectively. Once the SEARCH/RETRIEVE series has been completed, the user should be returned to the main menu. From the main menu the user can then initiate additional searches, input lessons or print/sort the lessons retrieved.

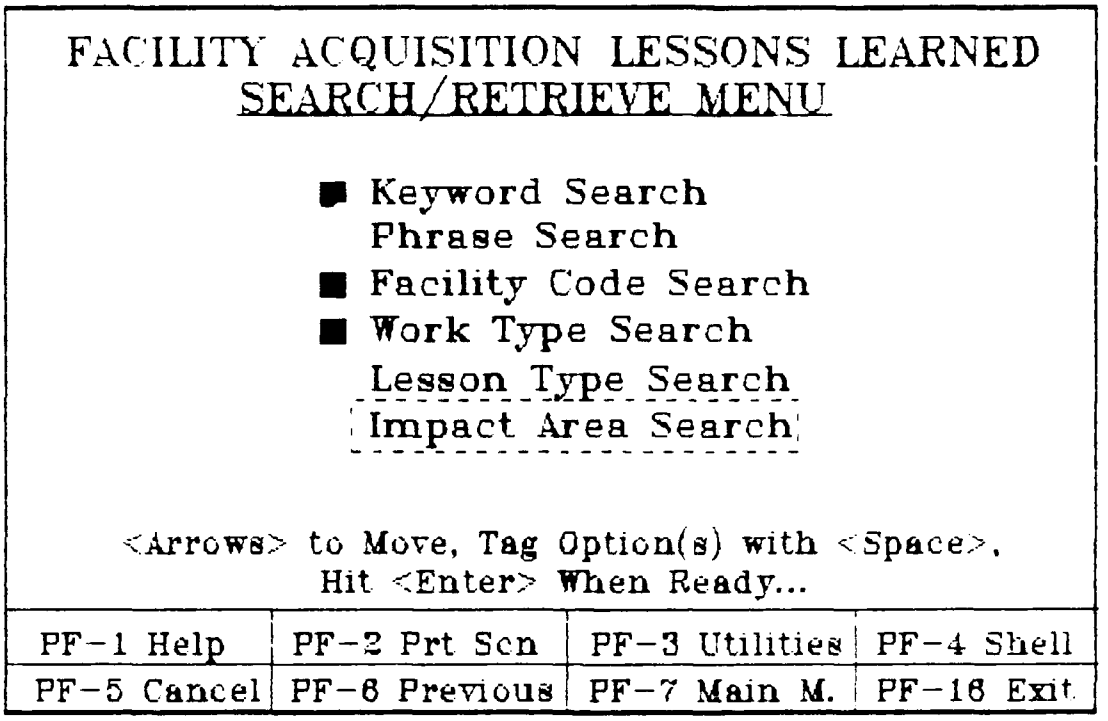


Figure 19. Proposed Search/Retrieve Menu

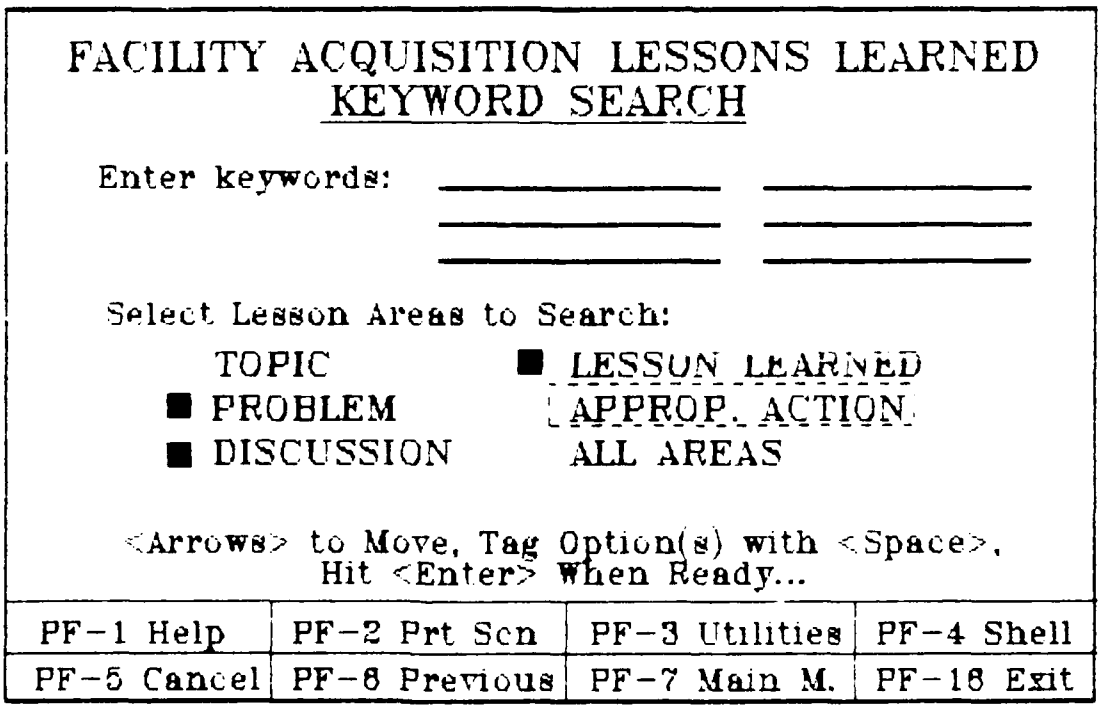


Figure 20. Proposed Keyword Search Menu

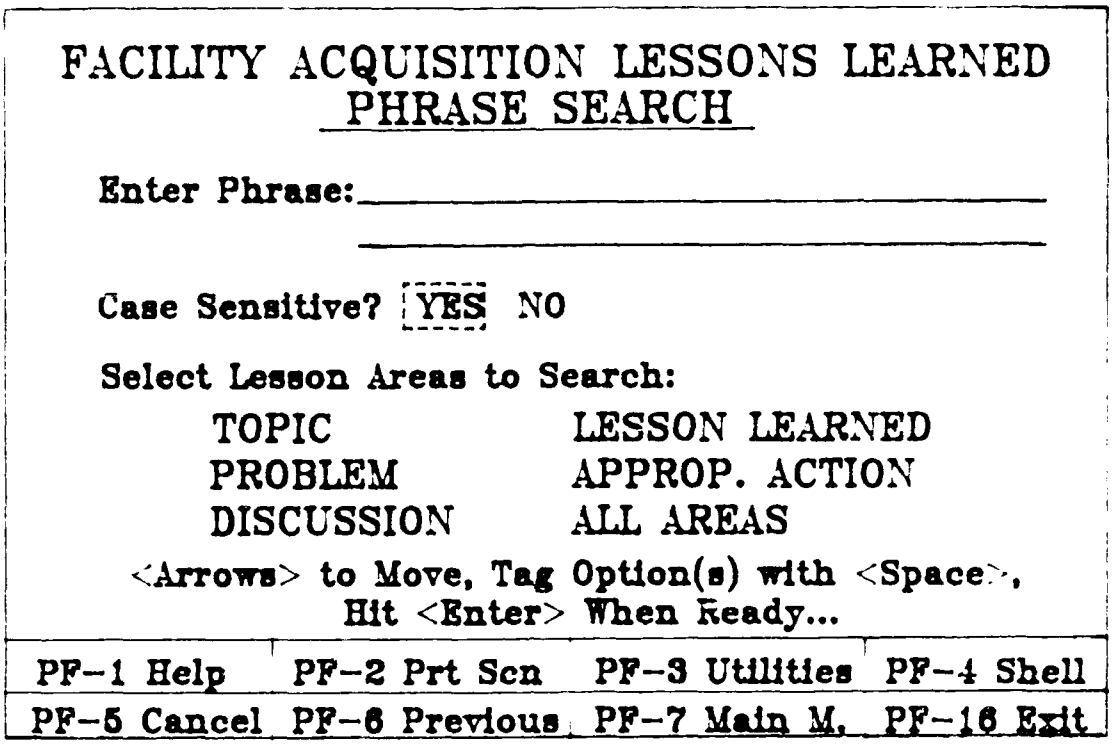


Figure 21. Proposed Phrase Search Menu

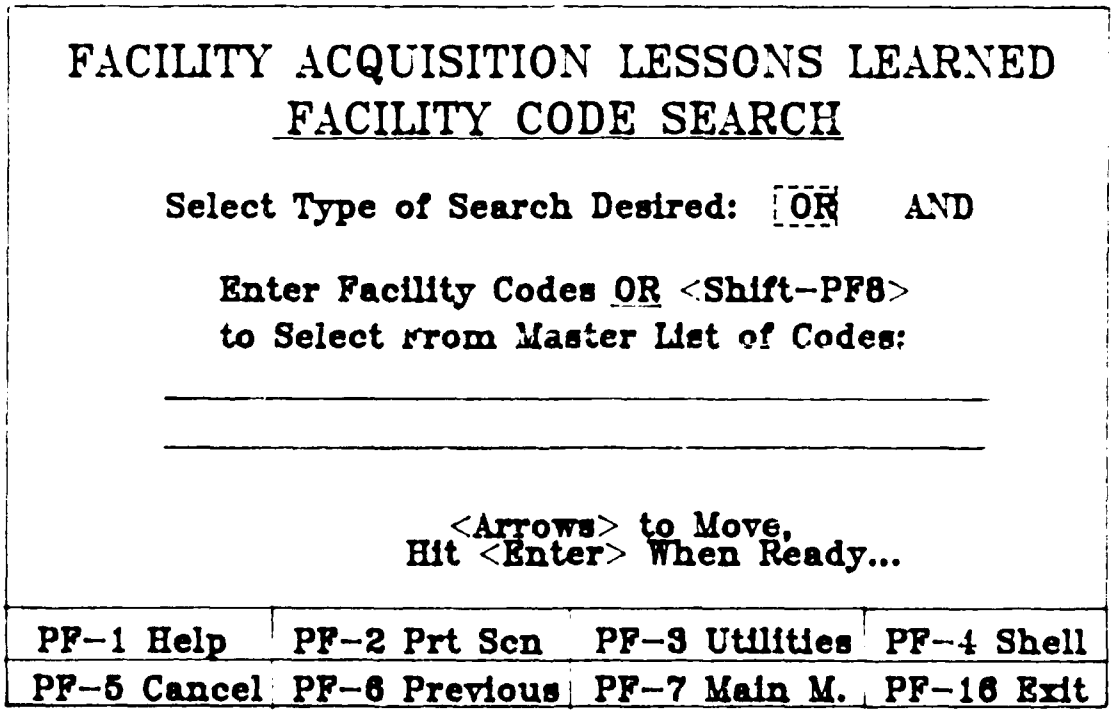


Figure 22. Proposed Facility Code Search Menu

Input Lessons. Engineers, inspectors, project managers, designers and construction managers should be allowed access to input lessons. Physical input of lessons should be accomplished using a fill in the blank approach. Selecting the INPUT LESSONS option at the main menu should present the user with a blank form showing each of the major areas listed in the content section of this chapter. A sample blank form is shown in Figure 23.

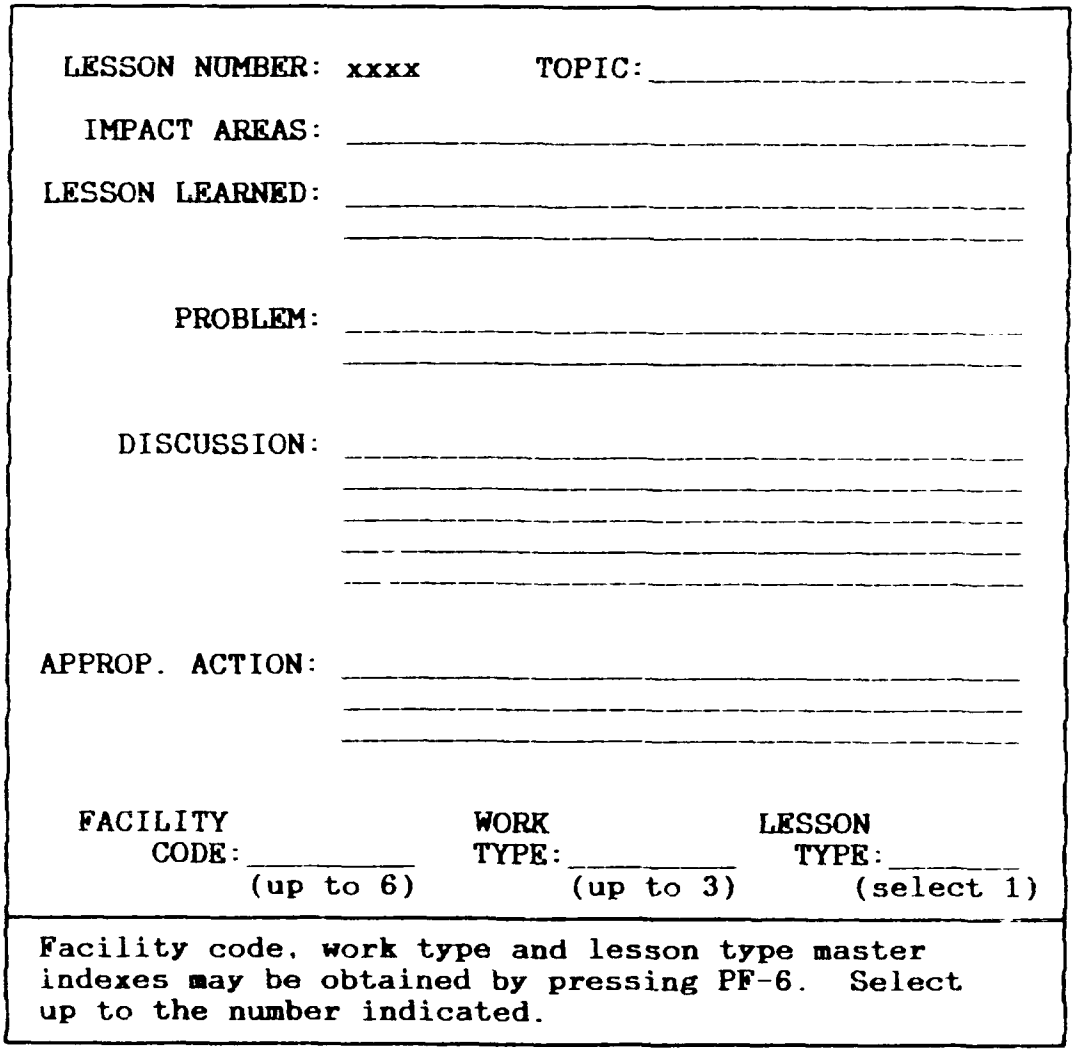


Figure 23. Proposed Lesson Input Form

The system should allow the user to fill in each of the blank areas, edit areas previously filled in and save the completed lesson. Lesson sections such as impact areas, facility codes, work type and lesson type should allow the user to retrieve master indexes of the approved areas,codes and types and select from the master indexes by toggling a light bar or hitting a "select this" key. When the user has completed filling in the form, the system should add a lesson learned number and allow the user to save, edit or totally discard the lesson. Selection of one of these functions should then return the user to the main menu. Lessons-learned should be validated by HQ AFESC.

Print/Sort. The PRINT/SORT capabilities of the system should allow the user to sort the lessons on facility code, work type, lesson type and impact area -- or any combination of these. Using a PRINT/SORT Menu similar to that shown in Figure 24, the user should be able to tag or select the desired fields for sorting. From this menu the user should also be provided a means to select the destination for the retrieved and sorted lessons. Potential destinations include the screen, printer or file. Once the user has made the desired selections and hit <Enter>, the system should prompt the user, "Do you want an Index and Table of Contents generated?". Next, the system should sort the lessons, and send them to the desired destination. If the destination is a file, the user should be allowed to specify the filename, extension, directory, etc.

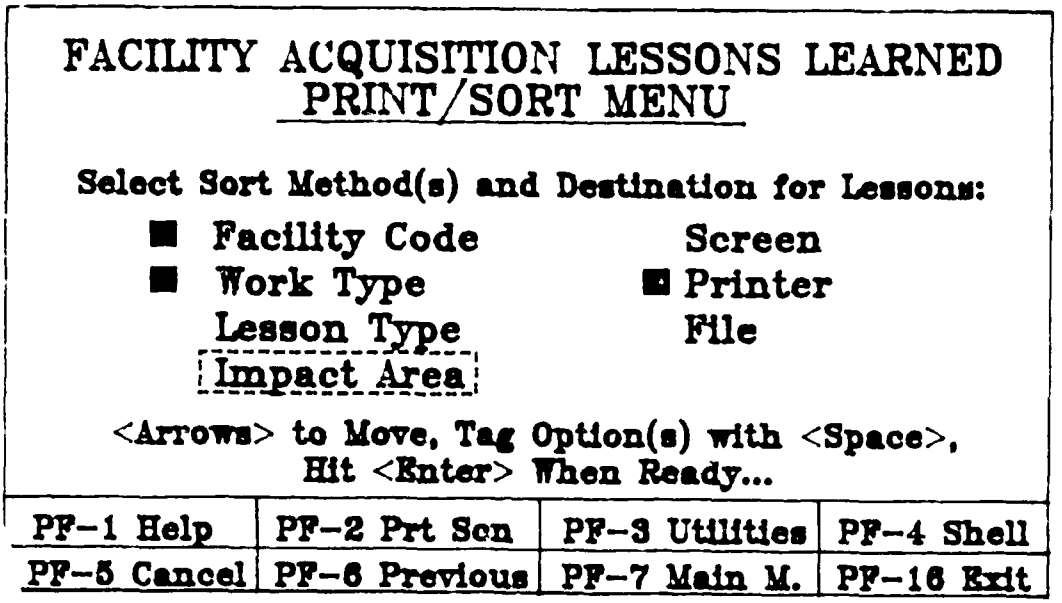


Figure 24. Proposed Print/Sort Menu

The PRINT/SORT Menu, shown in Figure 24, indicates the user has selected to sort the retrieved lessons on facility code and work type. The destination for the lessons is the printer. When the user hits the <Enter> key the system will then prompt for the filename, extension, directory, etc.

Figures depicting the work type, lesson type and impact area search menus are not shown here. These menus would be similar to the facility code search menu shown in Figure 22. All of the menus shown in this chapter are only suggested menus developed through the interviews with the users. All of the interviewees agreed that the proposed menus shown here are adequate to initiate a prototype system. It is expected changes in the menus will be necessary after the users have used and become familiar the system.

Summary

This chapter presented the findings regarding the research question, "From the user's perspective, how should the proposed lessons-learned MIS be structured?". Interviews with personnel from the AFRCEs and HQ AFLC/DER established a baseline description of the proposed MIS. The interviewees all stated the proposed system should be WANG-based, because the WANG is common to all AFRCEs and Civil Engineering units.

An "ideal system" was related by the users which would allow capturing and retrieving lessons-learned on both a visual and audio basis. From this ideal system, the interviewees supplied several insights into what a realistic system would be, within the financial and technical capabilities of Civil Engineering.

The proposed lessons-learned MIS should be menu-driven with minimal requirements for the user to type in a response. Instead, the user should be afforded the capability of selecting from a preset menu with very few keystrokes. Each level of the menus should be easily accessible and it should be equally easy to retrace or "back out" of any level. Programmed function keys should be used only for those functions common to all menus such as help, cancel, shell, exit, etc. Lightbar selection of menu specific options, such as SEARCH/RETRIEVE, INPUT LESSONS and PRINT/SORT, should be available to the user.

Lessons-learned should be generated and input into the system by those most familiar with Civil Engineering facility acquisition. In particular, engineers, designers, construction managers, project managers and inspectors should have full access to the proposed system. The principle system should be located at HQ/AFESC, Tyndall AFB.

Lessons should be standardized in format, but not constrained by limits in length or information content. Lessons-learned content should include -- impact areas, topic, lesson-learned, problem, discussion, appropriate action, facility codes, work type and lesson type. If possible, lessons should contain both sanitized information that does not reveal who actually was involved with the case from which the lesson was learned, and unsanitized information with very specific points of contact. Non-Air Force Civil Engineering users, such as the COE, NAVFAC and contractors, should be limited to the sanitized portion of the lessons.

Chapter VI presents the summary, conclusions and recommendations of this research.

VI. Summary, Conclusions and Recommendations

Summary

The objective of this research was to identify factors and procedures that should be considered when developing a construction management oriented, lessons-learned management information system for the Civil Engineering WANG computer.

To meet that objective this study considered several questions, including:

1. How are generic management information systems developed?
2. Are there on-line "lessons-learned" management information systems in use? If so, how have these systems been developed?
3. What common factors made the existing systems successful or less than successful?
4. How should a WANG-based lessons-learned system be developed to meet the needs of AF construction managers?
5. From the user's perspective, how should the WANG lessons-learned MIS be structured?

A review of the literature revealed management information systems development has progressed from the traditional systems analysis methodology to the more recent, user-developed methodology.

The traditional systems analysis methodology consisted of seven activities: 1) preliminary investigation, 2) requirements analysis, 3) prototype development, 4) system design, 5) software development, 6) testing and 7) implementation. The traditional systems analysis

methodology was often a very lengthy process because the systems analyst had to first determine exactly what the user needed. As a result, the traditional approach frequently failed to meet the user's needs both in terms of time and system function. The more recent user-developed methodology -- using prototypes and fourth generation application generators -- put the user in more direct control of the systems development. The systems analyst must still provide the structure and discipline required in systems development.

An understanding of WANG-specific applications development methodologies was obtained from the systems personnel at HQ AFESC. Due to the high demand for WANG applications in Civil Engineering, most WANG specific applications are user-developed through functional applications workshops. Functional applications workshops bring together the functional users of a proposed system; here, they determine the data content, menu structure and systems-data interface requirements. Once the user requirements are defined, a prototype is built. The prototype then becomes a working model for the functional users to evaluate, refine and improve. Iteratively, a new application becomes a reality.

Several on-line management information systems were explored, both general and lessons-learned oriented. Two of the largest DOD lessons-learned MIS's -- the Air Force Lessons-Learned System, and the Naval Aviations

Lessons-Learned System -- were researched in terms of development methodology, content and performance. Both the AFLL and the NALL were developed using a combination of the traditional systems analysis and user-developed prototype methodologies. Both the AFLL and NALL contain short descriptive lessons-learned dealing with weapons systems acquisitions. Finally, both systems performance appears to be meeting the needs of the users quite well.

Several factors contribute to the success of management information systems. The most important factors are system capability, user-friendliness, data accuracy and user involvement in the systems development stage. The user-developed approach to systems development increases all of these factors.

From the Civil Engineering construction managers perspective, a facilities acquisition lessons-learned system should be WANG-based, menu-driven, user-friendly and easily adaptable to the changing needs of the user. User recommendations for the characteristics of the system, data and manipulation of the data in the lessons-learned system were obtained through interviews with the AFRCEs.

According to the users, the proposed system should make maximum use of menus. From the menus the user should be able to select options with minimal keystrokes. Other than the input of lessons learned, the users wished to avoid having to fill out lengthy blank forms, as is currently required with many of the WANG/WIMS report generators.

Menus should allow option selection by lightbars. Only those functions that are common to all menus, such as print screen, previous screen, cancel, main menu, and exit should be PF-key based.

All levels of Air Force Civil Engineering construction should have access to the system for input, search and retrieval. Limited access to sanitized lessons (free of references to specific people, organizations and programs) should be available to contractors and other DoD construction personnel.

The system should be WANG-based, and centrally located at HQ AFESC. Lesson validation should be performed by HQ AFESC. Because the CPU costs associated with operating the WANG minicomputer are not significant compared to mainframe computer CPU costs, the lessons learned system need not be supplemented with a bulletin board type system similar to that used by the Navy. The menus envisioned by the users are illustrated in Chapter V.

Conclusions

This study began with a search for the for the definitive specifications of a WANG based, lessons-learned, management information system -- for Civil Engineering construction managers. However, just as there is never one best way to do almost anything, there are no unequivocal specifications for the proposed lessons-learned MIS.

Instead of quantifying and freezing the requirements for the proposed lessons-learned system, this research

determined the best requirements for lessons-learned systems are open and flexible. This research verified the need for a lessons-learned system to overcome the inexperience facing many USAF construction managers.

A starting point, or descriptive prototype for the proposed system is available as a result of this research. Using the menus depicted in Chapter V, and the narrative explanations of the interactions and functions of those menus, a working prototype could quickly be generated using fourth generation application generators. Once this prototype is provided to the construction managers, further recommendations for system improvements are sure to follow.

Recommendations for Further Research

Considerable time and effort in this research was expended determining exactly what a lessons-learned management information systems is, how it works and if it works. Likewise, finding, using and assessing existing systems consumed much of the limited research time available. Consequently, in hind-sight, insufficient time was available to determine specifically how a WANG based, lessons-learned system should be structured.

Travel time and funding limitations prevented gathering opinions and ideas from all levels of Air Force Civil Engineering construction management. Instead, only AFRCE level managers insights were obtained.

Additional research should be conducted to further the development of a lessons-learned MIS for construction managers. The findings presented in Chapter V should be converted into an actual prototype by HQ AFESC, Tyndall AFB. That prototype should then be provided to as many Civil Engineering construction management areas as possible. After sufficient time has been allowed the users to evaluate the prototype, additional recommendations and concepts should be collected either through surveys or delphi groups. Iteratively, a working MIS could and should be developed. Although there may be no substitute for experience -- using lessons-learned is as close as one can get.

Additional research could also be conducted to determine if and how the existing Air Force Lessons Learned system at HQ AFALD/LSL could be used to meet the needs of Air Force Civil Engineering construction managers. This research focused on the development of a WANG-based lessons learned system, but the Air Force Lessons Learned system is also a viable alternative that should be explored.

Appendix A: Interview

[This first series of questions is designed to provide a simple profile of you, the user. Please feel free to elaborate on any area addressed or provide information beyond what is asked if you consider it important. Above all, there are no right or wrong answers. Again, the purpose of this portion of the interview is to provide a profile of you, the user].

USER PROFILE:

1. Name: 2. Date:

3. Current Position: 4. Phone:

5. How many years experience do you have in Const. Mgt?

6. What scope of construction have you worked?

7. What roles or positions have you held or performed?

8. Are you familiar with computers? To what extent?

9. Which ones are you most familiar with?

10. Have you ever written computer programs?

11. What languages?

12. Do you use computer(s) in your current job?

13. For what purposes?

14. Are you familiar with the WANG/WIMS?

15. How familiar? (Have you used it? For what purposes?)

16. Do you find the WANG user-friendly? (why or why not)

17. Are their other system you find more user-friendly?

18. Which ones and why?

19. Are you familiar with the WANG conventions? (PF keys, etc)

20. Are you familiar with the concept of on-line lessons learned systems? Have you ever used one?

[This second series of questions is designed to allow you to provide your input on the proposed system. The questions are grouped into three areas: general system parameters, lessons-learned structure and lessons-learned input and retrieval. In simple terms, these three areas address the system, data and data handling. Again, there are no right or wrong answers. Feel free to take any time required to think about an answer. If you prefer, we can pass and return to any question(s) you require more time to think about. If necessary I can even call you back later -- today, tomorrow or next week. Please consider yourself constrained only by your imagination.]

GENERAL SYSTEM PARAMETERS:

21. If you could "design" a LL system what would it be like?

22. What system would it be on?

23. What type of interface would it use? (mouse, icons, pull down menus, menu bars, command driven, etc.)

24. If you used a menu-driven system, how many submenus would you consider necessary? (Print, sort, search, any others?)

25. How much help facilities should be included?

26. Where should printing capability be included?

27. Should usage be mandatory?

27. Who should have access to the system?

29. Any further ideas on the system in general?

LESSONS-LEARNED STRUCTURE

30. How long should a typical lesson be?

31. Is there a maximum recommended length?

32. What major types of lessons would you envision?

33. What level of data would you include in lessons?

34. How would you organize the data to constitute a lesson? (cat code, fac type, specification section, other?)

35. Are there any keywords or codes that each lesson should contain such as facility type, facility area, etc?

36. Should the lessons be santized?

37. Any additional ideas on the structure/content of the lessons?

LESSONS-LEARNED INPUT/RETRIEVAL

38. In general, how would the lessons be stored/retrieved?

39. Who should write the lessons?

40. How should the lessons be added to the system?

41. Who should have capability of adding or deleting lessons?

42. How should the lessons be retrievable?

43. Is word searching or full phrase searching necessary?

44. If so, how many keywords are necessary?

45. Is indexing or generating a report important?

46. Should system indicate "X lessons found?"

47. After search is complete, how would you want the data portrayed? (Lesson titles, abstracts, leasson learned, discussion, recommended action, all or some of above?)

48. Is lessons sorting capability necessary?

49. Any additional ideas on lessons input/retrieval?

[Your assistance in this research of on-line lessons-learned systems is greatly appreciately. Your time and insight into this study has helped to ensure that when a facilities acquisition lessons-learned system is built, it will meet the needs of the user. If you think of any additional information you might like to add later, feel free to call me. Again, thank you.]

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This thesis was based on the hypothesis that Air Force Civil Engineering construction managers could lessen the impact of inexperience through the use of lessons-learned. The thesis examined the potential for developing an on-line management information system (MIS) to provide better storage and retrieval of lessons-learned. Emphasis was placed on developing a WANG-based system that would be accessible at all levels of Civil Engineering construction.

Research consisted of reviewing MIS development methodologies, investigating several existing information systems - both general and lessons-learned oriented - and determining the user's requirements for the proposed MIS.

The objective of this research was to identify factors and procedures that should be considered when developing a construction manageme.. oriented, lessons-learned management information system for the Civil Engineering WANG computer. The process involved reviewing pertinent literature, logging onto and using existing on-line information systems and interviewing construction managers at the MAJCOM and AFRCEs.

Conclusions from this research indicated on-line information systems are well suited to lessons-learned. All of the AFRCE construction managers interviewed stressed additional use of lessons-learned is necessary. Further, the construction managers stated the proposed system should be WANG-based, menu-driven, user-friendly and easily adaptable to the changing needs of the user. Menus and system characteristics for a prototype lessons-learned MIS are outlined in the research. The author recommended a WANG-based lessons-learned MIS prototype be developed, using the research findings as a starting point, with further refinement through a more broad-based, user involvement.